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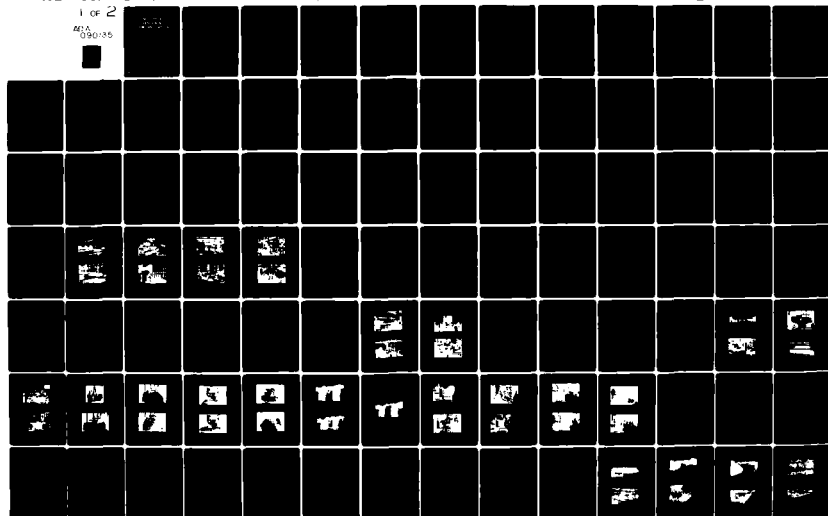
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# INDUSTRIAL HARDENING DEMONSTRATION

FINAL REPORT

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first phase, purely analytical procedures were used to test the principles and techniques. These were applied at a number of industrial sites by personnel familiar with weapons effects and at a few of the same plants by in-plant personnel unexperienced with weapons effects; the results are compared. In the second phase, actual hardening exercises were carried out, both by personnel familiar with the manual and also by plant personnel entirely unassisted. These operations were documented with slides and/or movies, and information was obtained on time and personnel logistic requirements to complete the hardening efforts. Results of the analyses are presented and comparisons made which suggest significant benefits from self-help industrial hardening might be expected..

Additional phases are both planned and necessary. The self-help manual can only be developed into a practical tool through an iterative process involving input from industry and from weapons effects experts working together. Thus, additional plants need to be involved to obtain statistical data on variation in hardening potential and benefits, and to identify especially vulnerable industries and develop alternative options for these. Key concepts need to be tested in the field under blast loading conditions to ensure validity.

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(DETACHABLE SUMMARY)

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INDUSTRIAL HARDENING DEMONSTRATION

by

J.V. Zaccor, C. Wilton, and G. Shephard, Jr.

for

Federal Emergency Management Agency  
Washington, D.C. 20472

Contract No. DCPA01-78-C-0278, Work Unit 1124D  
Dr. Michael A. Pachuta, Project Officer

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Scientific Service, Inc.  
517 East Bayshore, Redwood City, CA 94063

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## (DETACHABLE SUMMARY)

### INDUSTRIAL HARDENING DEMONSTRATION

The report describes the initial testing program to evaluate a manual developed to enable U.S. industry to reduce its vulnerability to nuclear attack and to some aspects of natural disasters. The manual describes a process called industrial hardening, which includes any method to enable a facility to resist fire, missile, blast, and electro-magnetic pulse (EMP) damage to vital equipment; planning and execution are to be implemented entirely as a self-help program. The objective of this study was to test the feasibility of the industrial hardening and self-help concepts through analytical exercises conducted by individuals proficient in weapons effects and disaster analysis and by local plant personnel with little or no background on the subject, and to compare the two. These exercises assessed the vulnerability of industrial plants both before and after hardening, estimating the time and effort required to achieve the vulnerability reduction. These were then checked against data obtained by conducting hardening exercises. The information obtained provides a quantitative measure of the potential significance of industrial hardening as well as initial input on how close to that potential a self-help program might come. The data are summarized in the attached tables.

Ten plants representing different industries were studied, and analyses were completed at nine that were extensive enough to yield assessments of the change in vulnerability. The increase in resistance to nuclear attack ranged from 6 to 18 psi at six plants; two plants were rendered essentially invulnerable because of complete removal to a host area; and one plant's vital operations were all rural already so that loss of this plant would not have appreciable effect on production. To give some idea of the effectiveness of this change, consider that even the smallest change (from 2 to 8 psi) would reduce weapon effectiveness

for industrial damage by approximately 84% (i.e., the 8 psi ring around ground zero is only 16% of the area of the 2 psi ring).

In the second phase of the program, hardening exercises were conducted at four plants. Slides and/or movies were made of the operations conducted at three of these plants, one of which was done by Scientific Service, Inc. (SSI) personnel in several stages in order to obtain pictures. At the other plants, the owner/managers did all the planning (in advance) and two of these outlined proposed hardening operations to SSI personnel so that the cameras could be set up to document the hardening exercise. The exercises were conducted entirely by in-plant personnel and completed in one day.

VULNERABILITY CHANGE DUE TO HARDENING AS AN INCREASE  
IN OVERPRESSURE EXPECTED BEFORE MODERATE DAMAGE RESULTS TO KEY EQUIPMENT

| Plant                                  | Before<br>Hardening<br>(psi) | SSI<br>Assessed<br>Improvement<br>(psi) | In-Plant<br>Personnel<br>Assessed<br>Improvement<br>(psi) | After<br>Hardening<br>(psi) |
|--|------------------------------|---|---|-----------------------------|
| Metal Caster                           | 2                            | 6                                       | 3   | 8                           |
| Electrical Equip-<br>ment Manufacturer | 2                            | 18                                      | —   | 20                          |
| Metal Stamping                         | 2                            | 14                                      | —   | 16                          |
| Steel Fabrication                      | 2                            | 8                                       | —   | 10                          |
| Food Processor                         | 2                            | invulnerable <sup>(a)</sup>             | —   | invulnerable <sup>(a)</sup> |
| Utility                                | 2 <sup>(b)</sup>             |   |   |                             |
| Wood Products<br>Manufacturer          | 2                            | 18                                      | —   | 20                          |
| Small Job Shop                         | 2                            | invulnerable <sup>(c)</sup>             | (c)   | invulnerable <sup>(c)</sup> |
| Electronic Equip-<br>ment Manufacturer | 2                            | invulnerable <sup>(c)</sup>             | —   | invulnerable <sup>(c)</sup> |
| Precast Construction                   | 2                            | 5                                       | 15 <sup>(d)</sup>   | 17                          |

— Not attempted; SSI assessment only

- (a) Mandatory food processing operations of this company all take place in rural areas, and only final "convenience" packaging takes place in this plant. Some of the equipment could be readily salvaged for other uses by other plants, but such analysis was outside the scope of the present study.
- (b) Not analyzed or assessed because this utility's resources are already well dispersed geographically.
- (c) Moved to host area, where overpressure is presumed to be 2 psi. If host area is not targeted, it may be assumed that these two plants have become "invulnerable".
- (d) The proprietor was innovative, deciding to enter a new business in the post-attack environment wherein his most vulnerable equipment would no longer be needed, hence the discrepancy between assessed improvements.



# COMPARISON OF ESTIMATED AND ACTUAL PLANNING AND EXECUTION TIMES

| Plant                                    | Planning Effort      |                                 |                          | Estimated Phase II Effort |                          | Actual Hardening Effort                |                          |                           |
|--|----------------------|---------------------------------|--------------------------|---------------------------|--------------------------|--|--------------------------|---------------------------|
|  | Man-Hours<br>Phase I | Number<br>of Men<br>Phase II(a) | Elapsed<br>Time<br>(hrs) | Man-<br>Hours<br>of Men   | Elapsed<br>Time<br>(hrs) | Man-<br>Hours<br>of Men<br>Used/Avail. | Elapsed<br>Time<br>(hrs) | % of<br>Plant<br>Hardened |
| Wood Products<br>Company                 | 4                    | 4                               | 2                        | 8                         | 500 (b)                  | 24                                     | 36                       | 20                        |
| Small Job Shop                           | 15                   | 1                               | 1                        | 16                        | 12                       | 2                                      | 6                        | 100                       |
| Electric/<br>Electronics<br>Manufacturer | Unknown              |                                 |                          | Not estimated (c)         |                          | 64                                     | 8/16                     | 100                       |
| Precast<br>Concrete Yard                 | 12                   | 3                               | 1                        | 15                        | 16                       | 4                                      | 7                        | 100                       |

(a) Logistic planning for hardening operations.

(b) One hundred hours if sandbags were filled in advance; forty hours if equipment skidded into a ditch, covered with heavy plastic, and protected with backfill.

(c) Four men required five days to relocate entire plant and return it to full production. It was estimated that evacuation required forty percent of this effort.

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Dr. Pachuta and the authors find it impossible to thank adequately those in industry who provided access to plants, information, time and effort. Without participation and input from industry at all levels, it is highly unlikely that a practical self-help manual could ever be developed and tested. To the many individuals who gave unstintingly of their time to help evaluate the concept of self-help for industrial preparedness, we apologize for not thanking each of them individually here. Their efforts in reading the manual and in providing comments and criticisms are, nevertheless, greatly appreciated.

We also wish to acknowledge a special indebtedness to those who participated in hardening exercises so that we could record these implementations on film and determine reasonable time and materials requirements. We need many more such contributors and exercises.

Finally, we should like to thank Bill Sugg and George Kamburoff for locating industrial participants; George Kamburoff and Joe Boyes for conducting the many hardening analyses; Joe Boyes and Mike Reeder for their photographic support; Maureen Ineich for the considerable artwork involved in producing slides, films, and reports; and Evelyn Kaplan and Larue Wilton for putting up with the many revisions and for providing the time-consuming but necessary editing support.

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## Section 1 INTRODUCTION

### BACKGROUND

This report summarizes the initial testing phases of a prototype manual, which was designed to provide a practical procedure that can be applied by industry to reduce vulnerability to nuclear weapons effects and to some aspects of natural disasters. This ongoing program to test the self-help concept and to provide a basis for upgrading of the manual is being conducted by Scientific Service, Inc., for the Defense Civil Preparedness Agency (now, Federal Emergency Management Agency) under Contract No. DCPA01-78-C-0278.

A general description of the contents and objectives of the manual being tested is important to an understanding of the test program. The manual was developed by Scientific Service, Inc., for the Defense Civil Preparedness Agency, under an earlier program.\* This manual is designed as a guide for industrial personnel in planning and executing programmed activities that use plant resources to reduce the vulnerability of plant equipment to nuclear threats and to comparable aspects of natural disasters. The process of reducing vulnerability within industry in general has been termed "Industrial Hardening" and is described briefly below.

As used in this report industrial hardening includes any methods to protect against fire, missile, blast, and electromagnetic pulse (EMP) hazards. Such methods include: removal of combustibles and potential missiles; strengthening or shielding of equipment against missiles and

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\* "Crisis Relocation Industrial Hardening Plan," SSI Report No. 7729-4, Scientific Service, Inc., Redwood City, California, June 1979. (Working Draft).

blast, or evacuating equipment to relatively risk-free areas; disconnecting equipment from antennas and power lines. To describe these different options, help define resource requirements to implement the options, and provide the benefit of decentralized management of a myriad of component tasks, the manual was developed as an integrated collection of booklets. Each booklet directs an activity and is intended to be self-contained with respect to instructions, examples, and worksheets.

The booklets generally guide users in methods to assess, gather, and commit resources more efficiently. Important elements of the process include determining the relative importance and vulnerability of each item of equipment, establishing priorities for hardening, and developing a range of options for hardening facilities and equipment based on those techniques most appropriate to local circumstances.

The research efforts reported here are part of a comprehensive program that must be completed before industrial protection can be applied on a national scale. Five program elements necessary to this overall program are as follows:

- I. Make an initial, general analytical assessment.
  - A. Determine the vulnerability of several different kinds of plants before and after hardening and estimate the time and effort required —
    - 1) As an analytical exercise conducted by individuals proficient in evaluating nuclear weapons effects;
    - 2) As an analytical exercise conducted by local plant personnel not knowledgeable in the subject.
  - B. Analyze the differences between I A 1) and I A 2); interview the in-plant analysts and attempt to identify the reasons for differences; and recommend changes in the manual that would reduce these differences.

II. Make an initial, general experimental assessment.

- A. Conduct hardening exercises (preferably at the same plants) to determine actual times and material and personnel resources required to harden.
- B. Record the hardening exercises on film for future development as training films, for public relations, etc.
- C. Analyze the differences between II A and I A; use the analysis to improve estimates of vulnerability changes generally achievable.

III. Conduct laboratory and field tests of selected hardening methods to obtain experimental data on hardened vulnerabilities.

- A. Conduct shock tube studies to establish dynamic and overpressure damage levels for selected hardening schemes. For example,
  - 1) Examine the effect of placing industrial equipment in a channel between two berms as a function of channel width and berm height.
  - 2) Evaluate the effect of banding or welding clumps of equipment together on the anchoring requirements.
- B. Conduct field tests on full-size equipment to verify the shock tube studies.

IV. Conduct a statistical assessment.

- A. Conduct both analytical and experimental assessments of hardening at a statistically significant cross-section of plants, for one or more specific industries.
- B. Identify the important differences and similarities insofar as hardening to reduce vulnerability is concerned.

- C. Extrapolate the above data to assess the nationwide impact of a nuclear attack insofar as selected industries are concerned.
- D. Consider the merit of applying or developing a general procedure for extrapolating to assess all industry.
- V. Conduct an analytical assessment of the vulnerability of the entire U.S. industry before and after hardening.

Other elements of this comprehensive program should include the specific problems of critical or essential facilities; i.e., those industries or organizations that are necessary to support military requirements and the crisis relocation program. These will require hardening techniques to allow operation of the equipment and processes during the crisis period and will necessarily include key worker shelters.

#### OBJECTIVES

The principal objectives of the Phase I and Phase II efforts, which were the subject of this work, were to make initial tests of the feasibility of the self-help concept and to assess the expected gain from industrial hardening. These tests and assessments depend on identifying and answering as many questions as possible regarding the effectiveness and practicability of the manual in actual use.

Perhaps an equally important factor in such a program is one that is scarcely mentioned; i.e., the problem of getting participation by industry. Not many in industry have either the interest or the time to be bothered with the questions of nuclear or other disasters for the simple reason that they seem remote possibilities. Hence, developing industry interest and response is virtually as important as developing a plan. Appendix A provides two accounts of industry first encounters, plus the rationale for the response of a third industry contact. Of course, some of these will be successful and some will not. In order to get on with

the manual evaluation process, we have not investigated the reasons for the different attitudes — which is a complex subject in itself; rather, we have built on those situations where the response was positive.

The specific objective of Phase I was to initiate analytical testing of the industrial hardening manual — both by those proficient and by those inexperienced in weapons effects — to determine the gap between them in applying it. An inherent part of this task was to use the information to establish what sorts of changes would be needed to bring these closer together so that such changes eventually could be incorporated into the manual to improve it.

The specific objective of Phase II was to conduct hardening exercises to obtain slides and/or movies of typical hardening options (i.e., evacuation, hardening in place, moving and hardening) and to conduct a complete testing of the manual entirely with in-plant personnel. An inherent part of this task was to obtain hard data on time and manpower required, and to make comparisons of this empirical data with planning estimates to evaluate how realistic the estimates might be.

## Section 2 METHODS

### PHASE I

The ground rules applied for the Phase I assessment of the manual were keyed to the Phase I objective; i.e., a comparison of the "outcome" obtained when the manual was applied by those proficient in weapons effects (but unfamiliar with the plants) with the "outcome" when it was applied by plant personnel uninitiated in weapons effects (but completely familiar with the plant).

The outcome was entirely the result of a paper exercise involving estimation of time and materials to be allocated to complete the hardening tasks using materials and personnel on hand. The measure of outcome was principally the change in vulnerability achieved.\* Essentially the only constraint imposed for these analyses was to schedule a three-day phased withdrawal of plant personnel to the "host area". The phased relocation was presumed to evacuate 20%, 50%, and 90-95% of plant personnel by days one, two, and three, respectively.

Evaluation of overall changes in overpressure vulnerability that might be achievable by following the manual were taken as measures of the outcome. In assigning vulnerabilities, probabilities of occurrence of damaging events were not considered. Therefore, if a reasonable potential existed for damage from some kind of event, then it was assumed damage

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\* The change in vulnerability is determined in the process of applying the manual and is different for each piece of equipment. However, as a single index for the entire plant, the difference in ratings for the most vulnerable items necessary to production before and then after hardening is probably suitable.

would occur unless some action were taken. (Rigorous statistical treatment would be required to go further than this and define the frequency with which damage actually does occur. Such statistical treatment is at least an order of magnitude greater effort and entirely outside the scope of the current program.) The approach taken at this stage is conservative.

Booklets that are incorporated in the manual, or planned, are indicated in Figure 1. Two of these (Booklets #6 and #10) have not yet been completed, so only eight have been tested. (Completion of the two missing booklets is dependent on the output from a study of methods for upgrading structures. For the current effort, visits to industrial plants by SSI personnel provided an expedient temporary alternative.) Based on the observation that most plants use light-steel-framed, metal-paneled structures to house equipment, SSI personnel analyzed several of these and found that, generally, they are likely to be demolished at about 2 psi. Because there is reasonable potential the collapsing structure will become the source of principal damage to industrial equipment within, under our ground rules it is assumed this equipment is vulnerable at 2 psi. Consequently, in lieu of a booklet on structural analysis, 2 psi was stipulated to in-plant personnel of the plants visited to be used as the collateral damage potential.

Figure 2 (from Booklet #5, page 8) depicts the format used in the manual for cataloguing the equipment in an industrial plant; Figure 3 (from Booklet #7, page 8) depicts the corresponding format for establishing hardening priority; and Figure 4 (from Booklet #7, page 8) depicts the format for hardening decisions. In Figure 3, the number entered in the "Priority" column establishes the order for hardening activities: the lower the number, the higher the ranking for hardening attention at the stage depicted in Figure 4.

When the analysis is done well in advance, there is ample opportunity for evaluating alternatives and for making maximum use of hardening resources, which are catalogued on worksheets in another booklet (see

## CRISIS RELOCATION INDUSTRIAL HARDENING PLAN

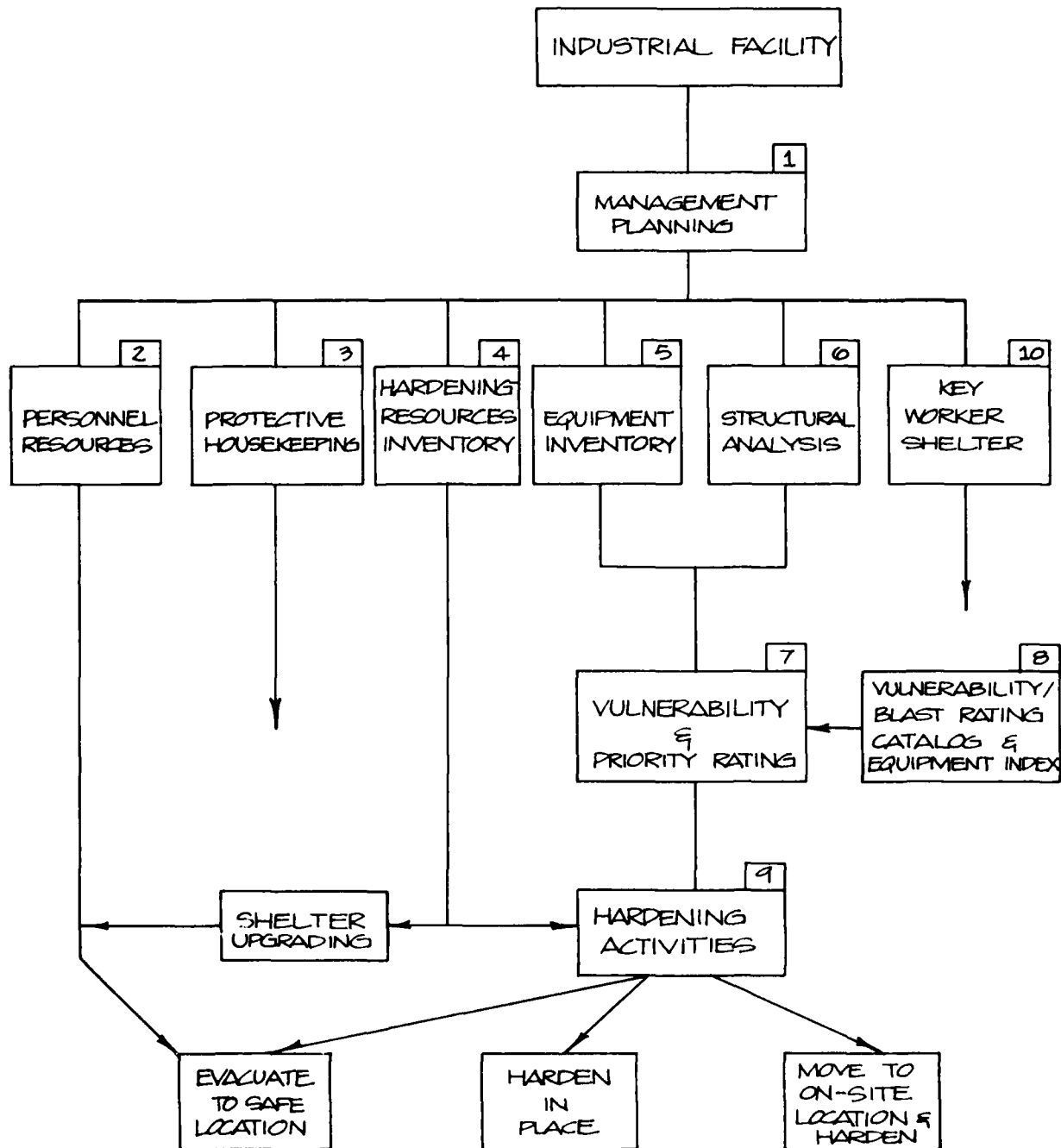


Figure 1. Flow Chart of Industrial Hardening Plan.





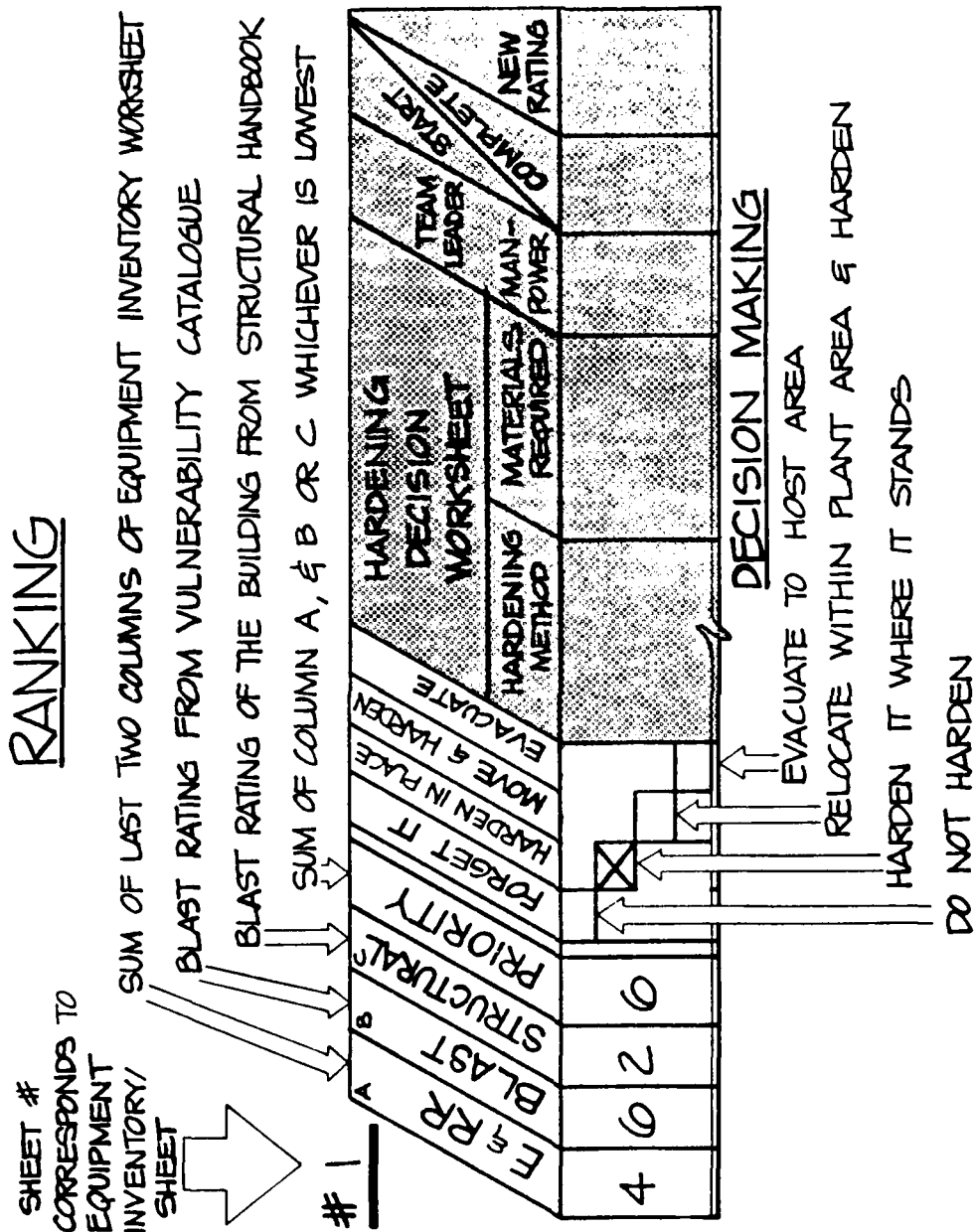


Figure 3. Hardening Priority Format.



Booklet #4, Figure 1). Being very realistic, time allocated in any real situation will be different at different plants — and one might expect some kind of "normal" distribution curve to describe it. Incentives, natural disaster preparedness benefits, and sharpening perceptions of growing international tension could all affect this distribution and shift the curve toward increased allocation of time to prepare and harden. This subject is a promising one for future consideration. For the present, it is of interest to assess what might be accomplished with a minimum level of effort. In short, a defensible realistic minimum is very probably what was applied by in-plant personnel for this study. Thus, any effort leading to more advance planning and preparation by industry should result in even better outcomes than will be found here (in a later section).

Figure 5 (from Booklet #7 page 8) shows a completed analysis for some of the equipment at one plant. The change in vulnerability is the difference between the last column, entitled "New Rating", and the corresponding figure in the "Priority" column. Change in vulnerability is in one-to-one correspondence with the change in overpressure that will cause light-to-moderate damage.

## PHASE II

Ground rules applied to the Phase II assessment were:

1. Conduct a complete hardening exercise at one plant;
2. Use a plant that participated in the Phase I effort;
3. Make both the Phase I and Phase II efforts of this participant entirely an in-plant exercise; i.e., without any input from SSI for either phase;
4. Document the hardening exercise photographically and without interfering with the hardening schedule.



No requirement was placed on when the planning was to be done, excepting that it be done in advance so that hardening operations could begin immediately on the day of the exercise using in-plant personnel with no prior knowledge of what was to take place. Estimates for time, manpower, and materials expected to be expended on the hardening exercises were part of the Phase I output from the participants. In addition, information was collected on the level of effort actually spent in planning.

The outcome of the hardening exercise was measured in terms of how well the actual time, manpower, and resources expended compared with that estimated, and whether sufficient information was provided in the manual to preclude any glaring oversights in planning and executing the hardening.

### Section 3

#### DISCUSSION OF RESEARCH ACCOMPLISHED

##### GENERAL

Fourteen plants contacted agreed to discuss industrial hardening, and ten of these participated to some degree in evaluating the manual. Thus, at least a partial evaluation of the manual was obtained at ten different kinds of plants. SSI conducted assessments in nine of these; at the tenth plant, a water utility, emergency planners went through all of the booklets as part of their normal assignment, but SSI personnel did not make an assessment.

Sufficient analytical assessments were completed in nine plants to calculate a vulnerability change. Of these nine plants, four agreed to have in-plant personnel go through an analytical assessment of one or more booklets. One of these plants was also assessed completely by someone from SSI who qualified as in-plant personnel — a former plant engineer from the participating plant. Among these four plants, three were fully analyzed by SSI and by in-plant personnel, enabling comparisons between assessments to be made.

For the Phase II effort; i.e., conducting hardening exercises, three plants agreed to participate: a wood products manufacturer, a precast concrete yard, and a small machine shop. By virtue of a well-planned move to minimize production loss, data were obtained at a fourth plant, indirectly.

Finally, comments were obtained from each participant regarding both general and specific aspects of an industrial hardening manual. These are presented with the data to help provide insight into the overall problem.

## PHASE I -- ANALYTICAL ASSESSMENTS

The participating plants comprised ten different industries: metal casting, electrical equipment manufacturing, metal stamping, steel fabrication, food processing, utility, wood products manufacturing, small job shop, electronic equipment manufacturing, and precast concrete construction. The last four in this series contributed to the Phase II study as well; they are discussed in detail later.

Table 1 summarizes what was undertaken at each plant (that is, booklets applied), both by SSI and by plant personnel. The Phase I studies for these plants are described in the following pages.



TABLE 1  
BOOKLETS COMPLETED FOR HARDENING ANALYSIS AT PARTICIPATING INDUSTRIAL PLANTS

| PLANTS<br>BOOKLET | PHASE I          |   |                            |                      |                   |         | PHASE II                         |                   |   |                         |     |       |
|-------------------|------------------|---|----------------------------|----------------------|-------------------|---------|----------------------------------|-------------------|---|-------------------------|-----|-------|
|                   | METAL<br>CASTING | ELECTRICAL<br>EQUIPMENT<br>MANUFACTURER | METAL<br>STAMPING<br>PLANT | STEEL<br>FABRICATION | FOOD<br>PROCESSOR | UTILITY | WOOD<br>PRODUCTS<br>MANUFACTURER | SMALL<br>JOB SHOP | ELECTRONIC<br>EQUIPMENT<br>MANUFACTURER | PRECAST<br>CONSTRUCTION |     |       |
|                   | SSI              | Plant                                   | SSI                        | Plant                | SSI               | Plant   | SSI                              | Plant             | SSI                                     | Plant                   | SSI | Plant |
| 1                 | ////             | ✓                                       | ////                       | ////                 | ////              | —       | —                                | REVIEW            | ////                                    | ////                    | ✓   | ✓     |
| 2                 | —                | —                                       | —                          | —                    | —                 | —       | —                                | —                 | —                                       | —                       | —   | ✓     |
| 3                 | ✓                | ✓                                       | —                          | —                    | —                 | —       | —                                | —                 | —                                       | —                       | —   | ✓     |
| 4                 | ✓                | ✓                                       | ✓                          | ✓                    | —                 | —       | —                                | —                 | —                                       | —                       | —   | ✓     |
| 5                 | ✓                | ✓                                       | ✓                          | ✓                    | —                 | —       | —                                | —                 | —                                       | —                       | —   | ✓     |
| 6                 | ✓                | 2 psi                                   | ✓                          | ✓                    | ✓                 | —       | ✓                                | 2 psi             | ✓                                       | ✓                       | ✓   | 2 psi |
| 7                 | ✓                | ✓                                       | ✓                          | ✓                    | ✓                 | ✓       | —                                | ✓                 | ✓                                       | ✓                       | ✓   | ✓     |
| 9*                |                  |   |                            |                      |                   |         |                                  |                   |   |                         |     | ✓     |

//// Not applicable to SSI (see Figure 1, page 9)

✓ Booklet completed

— Booklet not attempted

\* Applicable to Phase II only

### Metal Casting Plant

This was a large caster of specialty items with well over two hundred employees and facilities that cover several acres. Analysis showed the vulnerability level raised from 2 psi to 5 psi by in-plant personnel and from 2 psi to 8 psi by SSI personnel. The difference was found in the vulnerability of a transformer vault, which housed transformers key to electric furnace operation. The vault, like most structures, had a blast vulnerability near 2 psi so that both the vault and the plant structure were rated at this figure without hardening. However, SSI personnel determined the transformer vault could be made to resist 8 psi by shoring and sandbagging to strengthen it. This option involves structural hardening, which had not been treated in booklet form in the manual yet, so was not available to the in-plant analyst. A booklet to cover this subject is now in process and will be added to the manual, soon, to eliminate this gap.

The following data sheets provide copies of the hardening worksheets developed for the plant by SSI and by in-plant personnel; these data collecting and planning efforts took approximately 48 hours and 60 hours respectively. Note in these data sheets that the lowest "Priority" before hardening was (5), while after hardening it was (11). A six-point change in the minimum hardening priority implies the vulnerability of the plant has been raised 6 psi (and vice versa). The estimated time and manpower for the hardening effort was 3 days, using 80%, 50% and 5% of plant personnel on successive days for the task. The hardening strategies applied were removal of key records to host areas, and hardening-in-place or move-and-harden equipment. Sand-casting pits provided excellent onsite resources for the latter.

Comments by personnel at this plant were very pertinent. The president

and general manager felt there would be little response by industrialists unless some clear-cut current benefit to industry were identified "up front". He suggested that a more practical incentive to planning than a hypothetical nuclear attack would need to be presented; perhaps, concern for interruption in power supplies by earthquake, fire, rolling blackouts, etc., could induce industry to implement emergency planning as a means to minimize potential loss from a local (or large-scale) disaster.

Another reviewer at this plant suggested that a note be added somewhere to indicate the person assigned to complete the booklet on equipment inventory and hardening priorities should be selected primarily for his capability to visualize alternative options for production, equipment function, etc., in order to make appropriate decisions about relative importance of plant equipment. Many other practical comments were made as well, which will be applied in the revised manual.

*(Text continues on p. 31)*

# METAL CASTING PLANT

EQUIPMENT INVENTORY WORKSHEET # 1 PAGE 1 HARDENING DECISION WORKSHEET

BLDG. MAIN FLY AREA FRONT

SQUAD MEMBERS

| ITEM NO. | EQUIPMENT NAME AND DESCRIPTION  | QTY | SIZE            | REMARKS   | SNIT DOWN TIME | E | R | ELAST | STRUCTURAL | PRIORITY | REPAIRING | HARDENING METHOD   | MATERIALS REQUIRED   | SWELLING ALLOWANCE |
|----------|---|-----|-----------------|---|----------------|---|---|-------|------------|----------|-----------|--|--|--------------------|
| 1        | MOLD CORE OPENING WITH CAR ON RAILS   | 1   | 10' x 16' x 20' | BRICK, BOX TYPE GAS FIRED   | 0              | 4 | 4 | 0     | 2          | 10       |           | CAN BE JURY-RICKED FROM SALVAGE.   |  |                    |
| 2        | CUTPLAS CORE-FIRED ON METAL LENS BOLTED TO CONCRETE SLAB  | 2   | 60' x 16' x 20' | REFRACTORY LINER 1/2" REF BRICK INSIDE 1/2" IN STEEL SHELL EXTENDS 20 FT ABOVE ROOF OF MAIN BAY | 40 hrs         | 2 | 2 | 4     | 2          | 0        |           | IF NEEDED, GET ATTACHED TO JURY-RICKED FROM SALVAGE. CUT LARGE AMT. SALVAGE. MATERIALS & EQUIPMENT IN CHARGING ROOM. | RAIL CARPETS, FLOOR-S, ALL MATERIALS (CABLE, ETC.)                         | 117                |
| 3        | ELECTRIC FURNACE, 300 KW, MELTING POT WITH INDUCTION COILS  | 1   | 16' x 60' x 40' | ON 3-FIT HIGH MEZZANINE (STEEL) POT MOUNTED ON PIVOTS FOR ROTATING LINED STEEL POT              | 8 hrs          | 2 | 2 | 4     | 4          | 0        |           | FURNACE FILLED WITH COMPONENTS AND SPARE PARTS FROM THIS EQUIPMENT. POT FILLED WITH SAME. 100 CU FT.                 | SHOVELS, HAND HOIST, CABLE.  | 14                 |
| 4        | CONTROLS AND POWER CONDITIONING EQUIPMENT FOR 300 KW FURNACE  | 1   | 8' x 16' x 10'  | RELAYS, SWITCHES, METERS, LARGE CAPACITORS AND REACTORS INSIDE METAL CABINETS                   | 2 hrs          | 2 | 2 | 4     | 2          | 0        |           | DISCONNECT, BURY IN SAND PIT.  |  | 34                 |
| 5        | ELECTRIC FURNACE BOX, MELTING POT WITH INDUCTION COILS  | 2   | 8' x 16' x 10'  | LARGER VERSION OF ITEM 3 ABOVE. LINED STEEL POT   | 8 hrs          | 2 | 2 | 4     | 4          | 0        |           | SAME AS ITEM 3 ABOVE. 200 CU FT. OF CUTTERS. POT AVAILABLE FOR USE.  | SHOVELS, SUBPUMP, CUTTERS  | 13                 |
| 6        | CENTRAL STATION, ON MELT FEED POT, FOR 300 KW FURNACE   | 2   | 8' x 4' x 2'    | SAME AS ITEM 4 ABOVE. WITHOUT CAPACITORS AND REACTORS   | 2 hrs          | 2 | 2 | 4     | 2          | 0        |           | SAME AS ITEM 4 ABOVE.  | SAME AS ITEM 4 ABOVE.  | 34                 |
| 7        | TRANSFORMER VAULT WITH 2 POT + 1000 LB. W. 1400V. TRANSFORMER, TRANSFORMER AND CENTERS DISCONNECT CAPACITORS, REACTORS, SENSE LEADS | 1   | 25' x 25' x 40' | CONCRETE BLOCK PILE WITH REINFORCED CONCRETE REEF AND FLYER                                     | 2 hrs          | 2 | 2 | 4     | 2          | 0        |           | REMOVE FROM SLAB. REEF CUT OFF. SENSING INSIDE REEF. EQUIPMENT.  | TIMBERS, SAW, HAMMER, SAW, WRENCHES, HO, HAND TOOLS (MILKERS), SHOVELS (4) | 11                 |

PRIORITY = A+B or A+C (lowest sum)

DESCRIBE POSSIBLE COLLATERAL DAMAGE

MAIN BAY FILLET WITH LARGER FLASKS. MISC. EQUIPMENT. TRANSFORMER VAULT IS BLOCK BUILT CLOSE TO ALL ELECTRIC FURNACES AND CONTAINS THEIR TRANSFORMERS AND SWITCHGEAR. COLLATERAL DAMAGE: OVERHEATING (FROM ALL SIDES). USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED.

# 2 HARDENING DECISION WORKSHEET

EQUIPMENT INVENTORY WORKSHEET # 2 PAGE 2

**SQUAD MEMBERS**

← RATING →

PRIORITY =  $A+B$  or  $A+C$  (lowest sum)

|     | DETERMINE  | DESCRIBE POSSIBLE COLLATERAL DAMAGE |
|-----|--|-------------------------------------|
| 1.  | Identify the target and its location.                              |                                     |
| 2.  | Determine the type of weapon or munition used.                     |                                     |
| 3.  | Assess the potential impact on nearby civilian infrastructure.     |                                     |
| 4.  | Evaluate the risk of secondary explosions or fires.                |                                     |
| 5.  | Consider the possibility of contamination or environmental damage. |                                     |
| 6.  | Analyze the potential for displacement of civilians.               |                                     |
| 7.  | Investigate the impact on local economic activities.               |                                     |
| 8.  | Monitor for signs of psychological trauma or social unrest.        |                                     |
| 9.  | Document any injuries or fatalities among non-combatants.          |                                     |
| 10. | Report findings to relevant authorities for further action.        |                                     |

IT'S EVERYWHERE!

SUGGEST REMOVING OF BURNING EQUIPMENT

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION IF DISPOSED  
-LOCATES REMOVING OR EXISTING EQUIPMENT

**EQUIPMENT INVENTORY WORKSHEET**

BLOG MAIN PAY \_\_\_\_\_

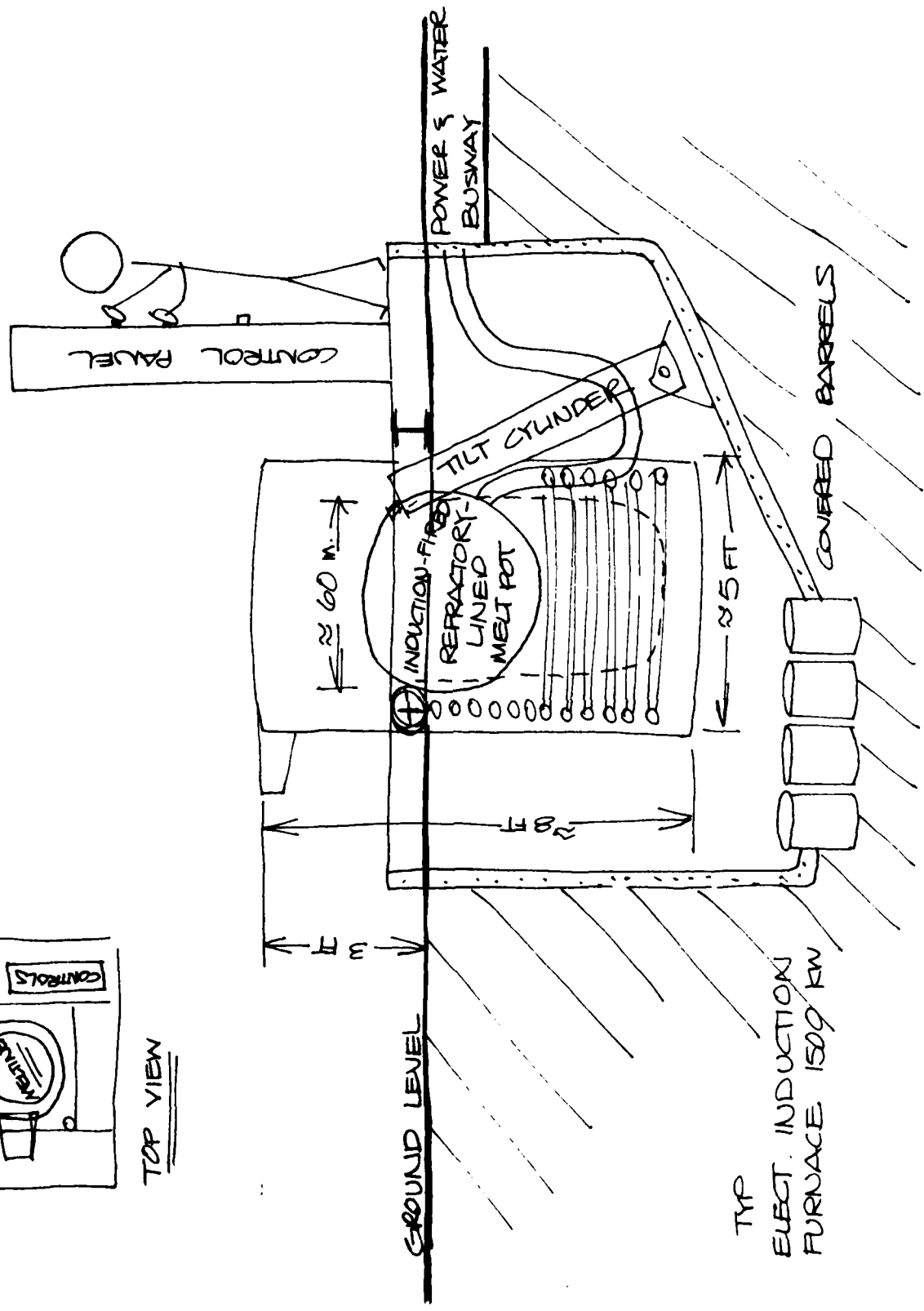
PAGE # \_\_\_\_\_ SQUAD # \_\_\_\_\_

LOG MAIN B  
AREA FRONT

| TIME<br>NO. | EQUIPMENT<br>NAME AND DESCRIPTION  | QTY | SIZE                        | REMARKS   | SUIT<br>DOWN<br>TIME | EL | RR | E+R | BLAST | STRUCTURE | PRIORITY                            | HAZARD<br>CLASSIFICATION | HAZARDING<br>METHOD  | MATERIALS<br>REQUIRED  | ON SITE<br>NEEDS<br>ESTIMATE |
|-------------|--|-----|-----------------------------|---|----------------------|----|----|-----|-------|-----------|-------------------------------------|--------------------------|--|--|------------------------------|
| 1           | MOLD CORE OVEN<br>WITH CAR ON<br>RAILS   | 1   | 10'<br>16'<br>20'           | BRICK, BOX TYPE<br>GAS FIRED  | 0                    | 4  | 4  | 0   | 2     | 0         | <input checked="" type="checkbox"/> |                          | KNOCK DOWN IF<br>TIME PERMITS  | INTERNATIONAL<br>H-25<br>PAILOADERS<br>SLURRIES<br>MANIFIESTS                              | 1/2<br>50<br>?               |
| 2           | CUPOLAS CORE FIRED<br>ON METAL LEGS<br>BOLTED TO<br>CONCRETE SLAB  | 2   | 60"<br>16"<br>20"           | REFRACTORY LINED<br>1/2 REF BRICK INSIDE<br>1/2-IN STEEL SHELL<br>EXTENDS 20 FT ABOVE<br>ROOF OF MAIN BAY           | 40<br>1/2<br>1/2     | 2  | 2  | 4   | 2     | 0         | <input checked="" type="checkbox"/> |                          | FILL WITH SCRAP<br>AND CORE OR<br>SAND;<br>TRUNKATE AND CUT<br>LOOSE ARE BACK-SHORE<br>AND SPREADS                             | 1/2<br>30<br>1/2<br>1/2<br>ALL MATERIAL<br>(CORE, ETC.) GOES<br>IN CHANGING<br>ROOM        | 1/2<br>30<br>1/2<br>30       |
| 3           | ELECTRIC FURNACE,<br>325 KW,<br>MELTING POT WITH<br>INDUCTION COILS  | 1   | 16"<br>16"<br>16"<br>24x42" | ON 5-FT HIGH<br>MEZZANINE (STEEL)<br>POT MOUNTED ON PIPES<br>FOR POURING<br>UNITED STEEL<br>(SEE SKETCH FOR SKETCH) | 0<br>1/2<br>1/2      | 2  | 2  | 4   | 2     | 0         | <input checked="" type="checkbox"/> |                          | FURNACE FILLED WITH<br>SCRAP TO 4" SPACES<br>PARTS FROM THROUGH<br>VAULT (IN SAND)<br>PIT FILLER WITH SAME<br>± 12" x 6" FT    | 1/2<br>22<br>1/2<br>1/2<br>SHOVELS<br>ANVIL<br>+ 2<br>DEPT<br>+ 1                          | 1/2<br>22<br>1/2<br>22       |
| 4           | CONTROLS AND<br>POWER CONDITIONING<br>EQUIPMENT FOR<br>325 KW FURNACE  | 1   | 8'<br>16"<br>16"<br>16"     | RELAYS, SWITCHES,<br>METERS, LARGE<br>CAPACITORS AND<br>REACTORS, MISC METAL<br>CABINETS<br>(SEE SKETCH FOR SKETCH) | 2<br>1/2<br>1/2      | 2  | 2  | 4   | 2     | 0         | <input checked="" type="checkbox"/> |                          | WIRES REMOVED FROM<br>TERMINAL STRIPS,<br>PANEL LAMP DOWN<br>REPLACE MELT DECK<br>2" x 12" x 8"<br>AND TEST WITH<br>WIRE BRIDE | 1/2<br>22<br>1/2<br>1/2<br>JOE<br>+<br>2   | 1/2<br>22<br>1/2<br>22       |
| 5           | ELECTRICAL<br>FURNACE<br>1500 KW<br>MELTING POT WITH<br>INDUCTION COILS  | 2   | 8'<br>16"<br>16"<br>16"     | LARGER VERSION<br>OF ITEM 3 ABOVE<br>UNITED STEEL POT<br>(SEE SKETCH)   | 0<br>1/2<br>1/2      | 2  | 2  | 4   | 2     | 0         | <input checked="" type="checkbox"/> |                          | SAME AS ITEM 3<br>ABOVE<br>± 12" x 6" FT OF POT<br>AVAILABLE FOR<br>USE  | 1/2<br>22<br>1/2<br>1/2<br>SHOVELS<br>ANVIL<br>+ 2<br>DEPT<br>+ 1                          | 1/2<br>22<br>1/2<br>22       |
| 6           | CONTROL STATION<br>ON MELT DECK FOR<br>1500 KW FURNACE   | 2   | 8'<br>16"<br>16"<br>16"     | SAME AS ITEM 4<br>ABOVE WITHOUT<br>CAPACITORS AND<br>REACTORS<br>(SEE SKETCH)                                       | 2<br>1/2<br>1/2      | 2  | 2  | 4   | 2     | 0         | <input checked="" type="checkbox"/> |                          | SAME AS ITEM<br>4 ABOVE  | 1/2<br>22<br>1/2<br>1/2<br>SAME<br>ITEM 4<br>+ 2<br>ABOVE                                  | 1/2<br>22<br>1/2<br>22       |
| 7           | TRANSFORMER VAULT WITH<br>EACH 500 KVA TRANSFORMER<br>1 EACH 500 KVA TRANSFORMER<br>1 EACH 500 KVA TRANSFORMER<br>1 EACH 500 KVA TRANSFORMER<br>1 EACH 500 KVA TRANSFORMER | 1   | 25'<br>25'<br>40'           | CONCRETE BLOCK<br>BLDG WITH<br>REINFORCED<br>CONCRETE ROOF<br>AND FLOOR   | 2<br>1/2<br>1/2      | 2  | 1  | 3   | 2     | 0         | <input checked="" type="checkbox"/> |                          | BEAM OUTSIDE<br>SANDRAGS INSIDE<br>EQUIPMENT   | 1/2<br>35<br>1/2<br>1/2<br>PAILOADERS<br>(2)<br>HAND DOLLS<br>(INSIDE)<br>3<br>SHOVELS (2) | 1/2<br>35<br>1/2<br>35       |

DESCRIBE POSSIBLE COLLATERAL DAMAGE  
MAIN BAY FILLED WITH LADLES, FLASKS, MISC. EQUIPMENT. TRANSFORMER  
VAULT IS BLOCK BLDG CLOSE TO ALL ELECTRIC FURNACES AND  
CONTAINS THEIR TRANSFORMERS AND SWITCHGEAR. COLLATERAL  
DAMAGE ENDEAVORED (FROM ALL SIDES)  
LOOSE BACK OF THIS WORKSHEET FOR SUBTYPE SHOWN EQUIPMENT LOCATION IF DESIRED

PRIORITY =  $A+B$  or  $A+C$  (lowest sum)



TYP  
ELECT. INDUCTION  
FURNACE 1500 KW

## METAL CASTING PLANT

PAGE # 2 HARDENING DECISION WORKSHEET

EQUIPMENT INVENTORY WORKSHEET # 2

ALSO MAIN BAY AND SIDE FLOORS  
AREA BEARS

SQUAD MEMBERS

| ITEM NO. | EQUIPMENT NAME AND DESCRIPTION   | QTY | SIZE            | REMARKS  | SHOT DOWN TIME       | E | RR | E+R | BLAST | STRENGTH | PRIORITY | NEEDS REPAIR                        | NEEDS MAINTENANCE        | HARDENING METHOD  | MATERIALS REQUIRED  | ESTIMATED COST | ESTIMATED TIME |
|----------|--|-----|-----------------|--|----------------------|---|----|-----|-------|----------|----------|-------------------------------------|--------------------------|---|---|----------------|----------------|
| 1        | ROLLOVER AND/OR VOLT SERVICERS   | 10  | 4' x 5'         | VERY HEAVY CONSTRUCTION AIR OPERATED BUILT (34" IN BULBS) SECURED TO LARGE CONCRETE MOUNTING IN GARAGE FOR SERVICE             | 0                    | 3 | 3  | 6   | 0     | 2        | 0        | <input checked="" type="checkbox"/> | <input type="checkbox"/> | LOWER CENTER OF GRAVITY SANDBAGS OR BERM  | 30 SANDBAGS PER MACHINE (OR 1 1/2 YDS SAND)                 | 10             | 10             |
| 2        | BOX-TYPE REFRACTORY BRICK  | 0   | 10' x 12' x 16' | BRICK ON CONCRETE PAD OLD AND IN POOR REPAIR ALONG BACK OF BOUNDARY BLOCKS   | 0                    | 3 | 4  | 7   | 2     | 2        | 9        | <input checked="" type="checkbox"/> | <input type="checkbox"/> | FILL TWO WITH THE BAGGED MALLING SUPPLIES LEAVE OTHERS DISASSEMBLE AT MAIN BOUNDING LAY IN MOLDING PITS STRIP PEDESTAL AND BURY ALSO SANDBAGS OR BERM PEDESTAL FORM | FORKLIFT AND DRIVER   | 11             | 11             |
| 3        | CONTINUOUS MIXERS SAND ALLOY TYPE ON FEDERAL (UNCOVERED)                                       | 3   | 8' x 10' x 30'  | HEAVY BASE BUILT TO CONCRETE PAD STEEL TRAILERS ON LARGE BEARINGS ARTICULATED MIDWAY IN TRAILERS                               | 0                    | 3 | 3  | 6   | 3     | 2        | 0        | <input checked="" type="checkbox"/> | <input type="checkbox"/> | REMOVE #2 AND BURY IN MOLDING PIT LEAVE #1 OPERATING  | HAND TOOLS AND CRANE, PLASTIC WRAPPING                      | 14             | 12             |
| 4        | AIR COMPRESSORS #1 AND #2 RECIPROCATING 12.5 HP 655 CFM @ 100 PSI TWO-STAGE WITH WATER COOLING | 2   | 5' x 5' x 5'    | BUILT (1/2 IN BULBS) TO CONCRETE BARS  | ONE AND A HALF HOURS | 2 | 2  | 4   | 0     | 0        | 0        | <input checked="" type="checkbox"/> | <input type="checkbox"/> | REMOVE #2 AND BURY IN MOLDING PIT LEAVE #1 OPERATING  | HAND TOOLS LARGE FORKLIFT                                   | 14             | 12             |
| 5        | AIR COMPRESSORS #3, #4, #5 40 HP 1005 CFM @ 100 PSI HORIZONTAL                                 | 3   | 5' x 3' x 10'   | SINGLE-STAGE HORIZONTAL RECIPROCATING WITH LARGE FLYWHEELS BUILT (5/8 IN BULBS) TO HEAVY PAD                                   | SAME                 | 3 | 2  | 5   | 0     | 2        | 7        | <input checked="" type="checkbox"/> | <input type="checkbox"/> | BURY ONE IF TIME PERMITS LEAVE OTHERS, OR SANDBAGS IN PLACE   | HAND TOOLS SANDBAGS SHOVELS                                 | 14             | 12             |
| 6        | SWING GRINDERS/CLIFF SAW SUSTAINED FROM HOIST, BUILT DRIVEN FROM 40 HP MOTOR ON FRAME PORTABLE | 0   | 3' x 2' x 10'   |  | 0                    | 3 | 3  | 6   | 3     | 2        | 0        | <input checked="" type="checkbox"/> | <input type="checkbox"/> | BURY IN MOLDING PIT   | RAIL CART AND FORKLIFT TO TAKE TO BURY                      | 14             | 12             |
| 7        | SPECTROGRAPH (LAB)   | 2   | 0               | TYPICAL CONTROL PANEL ENCLOSURE CONTAINS 4 X 1 X 3 CAST IRON STEEL VALUUM CHAMBER (5" DIAMETER) WITH 1" PANEL W/ VACUUM RESIST | 0                    | 3 | 1  | 4   | 2     | 2        | 0        | <input checked="" type="checkbox"/> | <input type="checkbox"/> | REMOVE AND LAY IN SAND BIN AND COVER  | FORKLIFT HAND TOOLS PANELS OF FORKLIFT FOR COVERS WITH SAND | 14             | 10             |

DESCRIBE POSSIBLE COLLATERAL DAMAGE

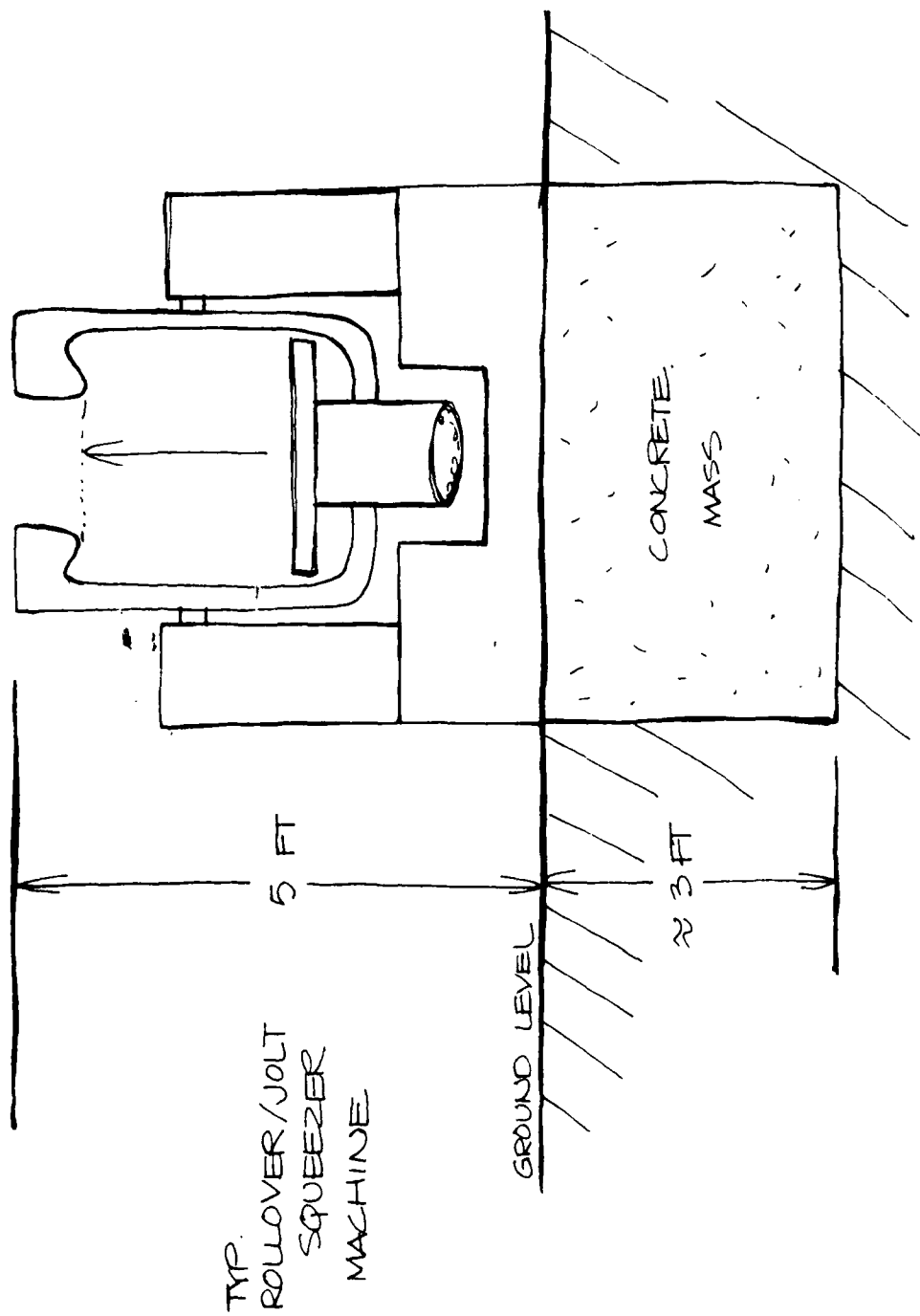
IT'S EVERYWHERE!

SUGGEST REMOVING OR BURYING EQUIPMENT

ON BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED

PRIORITY = A+B or A+C (lowest sum)

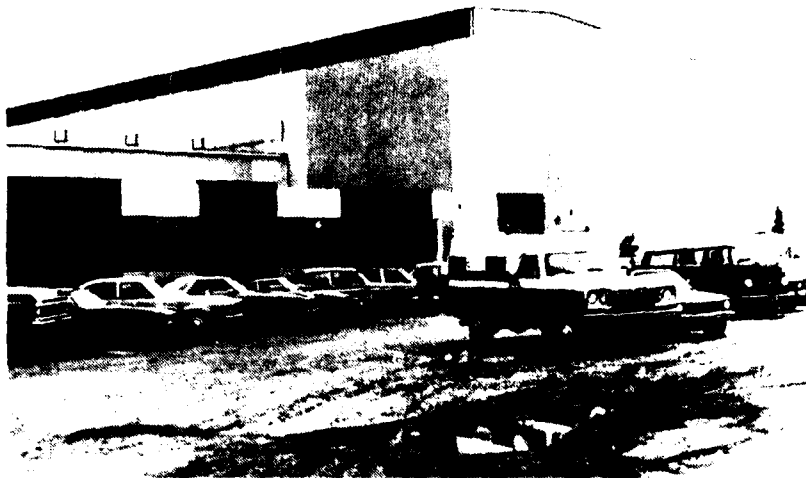




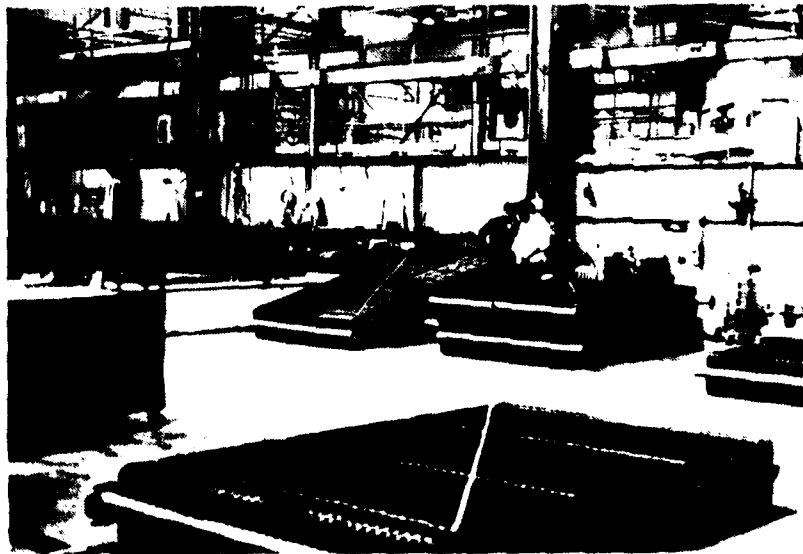
### Electrical Equipment Manufacturer

This plant is a producer of large utility transformers with over two hundred employees and over two acres of floor space. Figures 6 through 9 provide some idea of plant size and characteristic operations. Following these figures are copies of the hardening worksheets developed for this plant by SSI personnel. This planning effort took approximately 30 hours. On these data sheets, the lowest "Priority" before hardening was 6, and the lowest "New Rating" after hardening was 20+ corresponding to a minimum change of 14+ psi. A review of these 20+ ratings set the minimum improvement at 18 psi for this plant. The hardening was estimated to be completed by the end of day two. (In all the SSI analyses it was assumed three shifts would operate each day.) In the discussion with the plant engineer, he was asked what the absolute minimum equipment would be to enable the plant to return to a minimum level of production. After much thought and discussion he decided a low level could be achieved with just a cutting torch, welder, generator, fuel, and the raw materials salvaged.

*(Text continues on p. 47)*



A. Photograph of Facility

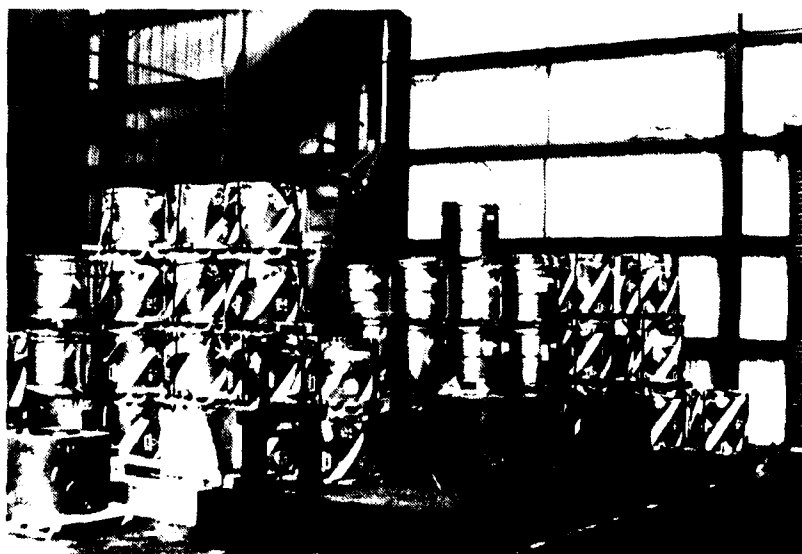


B. Cooling Fin Fabrication

Fig. 6. Electrical Equipment Manufacturer.



A. Wire Stock



B. Sheet Steel Coils

Fig. 7. Electrical Equipment Manufacturer.

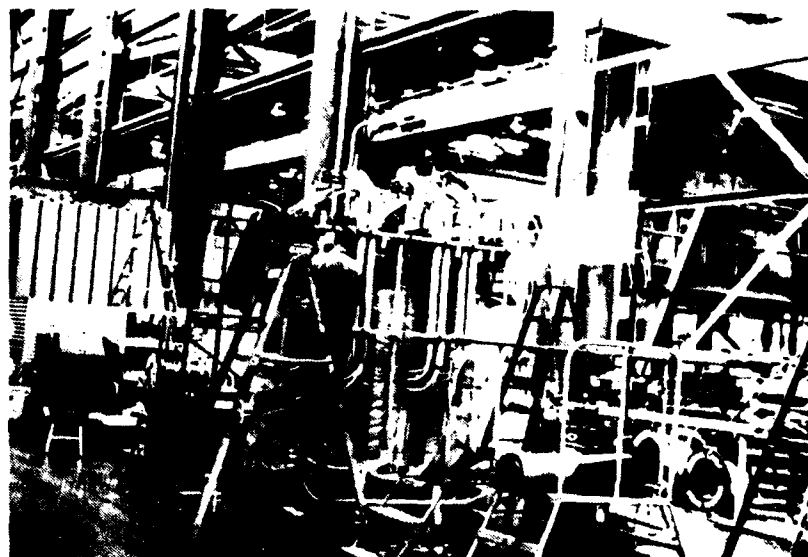


A. View of Main Corridor in Plant



B. Coil Fabrication Area

Fig. 8. Electrical Equipment Manufacturer.



A. Core Assembly



B. Completed Core

Fig. 9. Electrical Equipment Manufacturer.

[illegible]

DESCRIBE POSSIBLE COLLATERAL DAMAGE

ALL EQUIPMENT NEAR / AGAINST METAL WALL

AND BACK OF THIS WORKSHEET FOR SKETCHES AND WINDING EQUIPMENT LOCATION IF DESIRED

PRIORITY =  $A+B$  or  $A+C$  (lowest sum)

| ITEM NO. | EQUIPMENT NAME AND DESCRIPTION                      | QTY | SIZE              | REMARKS   | SHUT DOWN TIME | E | RR | BLAST |       |           |          | STRUCTURE | PRIORITY | ELECTRICITY | HARDENING METHOD   | MATERIALS REQUIRED                                       | ESTIMATED COST | REMARKS |
|----------|---|-----|-------------------|---|----------------|---|----|-------|-------|-----------|----------|-----------|----------|-------------|--|--|----------------|---------|
|          |   |     |                   |   |                |   |    | E+RR  | BLAST | STRUCTURE | PRIORITY |           |          |             |  |  |                |         |
| 1        | PARTITIONS PORTABLE, CORRUGATED ALUMINUM            | 5   | 7' 10'            | SURROUND SIX WELDING STATIONS WITH MANUAL WELDERS         | 0              | 4 | 4  | 0     | 2     | 2         | 10       |           |          |             | USE FOR COVERING BEHEATED LOADING AREA FILLED WITH SUPPLIES                      | NONE ONE FORK-LIFT                                       | 25             |         |
| 2        | PARTITIONS: METAL STAND ALONE ON 10' X 24' FEET (2) | 7   | 7' 12' 1/4" THICK | BETWEEN WELDING STATIONS IS FROM METAL WALL OF PAINT SHOP | 0              | 4 | 4  | 0     | 2     | 2         | 10       |           |          |             | USE TO COVER PERFORATED FLOOR IN SAND BLAST CABINETS                             | ONE FORK-LIFT  | 25             |         |
| 3        | WELDING TABLES APPROX 6X7 FT APPROX 4X5 FT          | 7   | 1' 1' 1' 1'       | TOP 1/2" TO 1" THICK WELDED TO HEAVY SUPPORTS             | 0              | 3 | 4  | 7     | 10    | 2         | 9        |           |          |             | PROTECTIVE HOUSEKEEPING; INVERT OUTSIDE  | ONE FORK-LIFT  | 25             |         |
| 4        | WELDERS - ELECTRIC ARC                              | 7   | 2 1/2' 3' 4'      | PORTABLE, PLUG-IN   | 0              | 2 | 3  | 5     | 4     | 2         | 7        |           |          |             | STORE IN TRANSFORMER CASE FOR BLAST AND EMP PROTECTION LARGE CASE IN INSIDE DACK | ONE (GAS) TO MOVE TO TRANSFORMER CASE INITIALY THEN NONE | 25             |         |
| 5        | GAS WELDING RIGS                                    | 3   | 1' 1' 1' 1'       | ACETYLENE WELDERS WITHOUT CARTS                           | 0              | 2 | 2  | 4     | 10    | 2         | ④        |           |          |             | LOWER INTO WINDING PIT AND FILL SPACES IN SAND BLAST PIT.                        | FORK-LIFT TO HANDLE BOTTLES                              | 30             |         |
| 6        | PUNCH PRESS ONE NO. 1/2 ONE NO. 2 1/2               | 2   | 3' 5' 7' 1'       | EACH WITH FOUR 5/8" BOLTS AGAINST WEST WALL (METAL)       | 0              | 3 | 2  | 5     | 4     | 2         | 7        |           |          |             | STORE IN SAND BLAST PIT. BAY 3 (2 ITEMS)   | HOIST, FORK-LIFT   | 25             |         |
| 7        | THREADING MACHINE (OSTER)                           | 1   | 2' 4' 4'          | AGAINST WEST METAL WALL NOT FASTENED DOWN                 | 0              | 3 | 3  | 6     | 6     | 2         | 8        |           |          |             | STORE IN SAND BLAST PIT. BAY 3 (2 ITEMS)   | HOIST, FORK-LIFT   | 25             |         |

DESCRIBE POSSIBLE COLLATERAL DAMAGE

PRIORITY = A+B or A+C (lowest sum)

THE BACK OF THIS WORKSHEET FOR SIGNATURES SHOWING EQUIPMENT LOCATION IF DESIRED



## ELECTRICAL EQUIPMENT MANUFACTURER

PAGE # 3 HARDENING DECISION WORKSHEET

EQUIPMENT INVENTORY WORKSHEET # 3  
SQUAD MEMBERS

| ID | EQUIPMENT NAME AND DESCRIPTION   | QTY | SIZE            | REMARKS  | SHUT DOWN TIME | E | R | Blast | Structure | Priority | Elevated | Flammable | Toxic | Explosive | Hazardous | Materials Required           | HARDENING METHOD  | ESTIMATED COST | 240 |
|----|--|-----|-----------------|--|----------------|---|---|-------|-----------|----------|----------|-----------|-------|-----------|-----------|------------------------------|---|----------------|-----|
|    |  |     |                 |  |                |   |   |       |           |          |          |           |       |           |           |                              |   |                |     |
| 1  | PAINT BOOTH FLAMMABLES   | 1   | 20' x 60' x 20' | METAL PALES 15 FT. APART FRAMED WITH SHEET METAL WALLS EQUIPPED WITH ELECTRICAL HOIST & CHAIN GENERATOR ON BOILERS | 0              | 3 | 3 | 0     | 2         | 2        | 0        | 0         | 0     | 0         | 0         | 0                            | REMOVE OR COVER FLAMMABLES (PROTECTIVE HOUSEKEEPING)            | 240            |     |
| 2  | SHEET METAL AND GLASS OFFICE STORAGE AREA ON TOP FOR BOXES   | 1   | 8' x 15' x 15'  | 3" BOLT IN EACH CORNER BOLTED TOGETHER CROSS TIES AND TURNBUCKLES  | 0              | 4 | 4 | 0     | 2         | 2        | 0        | 0         | 0     | 0         | 0         | N/A                          | N/A   |                |     |
| 3  | 1/8 CRANES (1/2 AND 1-TON CAPACITY) ELECTRIC HOISTS 20 FT VIBS ABOVE LATHES MILLS AND WELDING MACHINES | 10  |                 | 3 AGAINST WEST WALL 7 ON COLUMNS OPPOSITE SIDE BAY   | 0              | 3 | 2 | 5     | 0         | 2        | 7        | 0         | 0     | 0         | 0         | LADDER HAND TOOLS            | REMOVE CABLES FROM SOME FOR TIES HOISTS IN SAND BLAST PIT BAY 3 | 25             |     |
| 4  | BUSWAY 160 LINEAR FT 440 V WITH DISCONNECTS (40) 160 FT WEST WALL 160 FT BETWEEN BAYS                  | 2   |                 | AGAINST WEST WALL 12 FT HIGH ALSO ON COLUMN ROW # 1  | LAST           | 2 | 3 | 5     | 4         | 2        | 7        | 0         | 0     | 0         | 0         | REPLACE                      |   |                |     |
| 5  | ELECTRIC HEATERS (CONVERT) UP BY BUSWAYS   | 10  | 2' x 3' x 3'    | HANG UNDER BUSES   | 0              | 4 | 3 | 7     | 4         | 2        | 9        | 0         | 0     | 0         | 0         | NOT NECESSARY FOR PROTECTION | 25  |                |     |
| 6  |  |     |                 |  |                |   |   |       |           |          |          |           |       |           |           |                              |   |                |     |
| 7  |  |     |                 |  |                |   |   |       |           |          |          |           |       |           |           |                              |   |                |     |

RATING  
PRIORITY = A+B or A+C (lowest sum)

DESCRIBE POSSIBLE COLLATERAL DAMAGE

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED

## EQUIPMENT INVENTORY WORKSHEET # 4 PAGE 4

PAGE  
# 4

PAGE  
# 4

DATE \_\_\_\_\_ PAGE 2

DATE \_\_\_\_\_ PAGE 2

DATE \_\_\_\_\_ PAGE 2

[illegible]

DECEASE POSSIBLE COLLATERAL DAMAGE

PRIORITY =  $A+B$  or  $A+C$  (lowest sum)

TURN BACK OF THIS WORKSHEET FOR SIDE TONE'S SHOWING EQUIPMENT LOCATION IF DESIRED

## ELECTRICAL EQUIPMENT MANUFACTURER

PAGE # 5 HARDENING DECISION WORKSHEET

PAGE # 5

EQUIPMENT INVENTORY WORKSHEET # 5

SQUAD MEMBERS

BLOS AREA BAY 2

| ITEM NO | EQUIPMENT NAME AND DESCRIPTION   | QTY | SIZE      | REMARKS   | EST. WORK TIME | RR | E+R | BLST | SPRINT | PRIORITY | ENVIRONMENTAL | HARDENING METHOD  | MATERIALS REQUIRED                                 | EST. COST |
|---------|--|-----|-----------|---|----------------|----|-----|------|--------|----------|---------------|---|--|-----------|
| 1       | BRIDGE CRANE (ELECTRIC) 10/25 TON PENDANT CONTROL 50 FT SPAN ELECTRIC    | 1   |           | BUS-FED ELECTRIC APPROX 25 FT. HIGH ON RAILS                            | 0              | 2  | 4   | 0    | 2      | ②        |               | MOVE TO SAND BLAST CABINET GUY AND BRACE OVER PIT                   | WELDERS<br>HOIST<br>CABLE<br>HAND<br>POLES         | 20        |
| 2       | GAS WELDING REG ACETYLENE, NO DOLLIES                                    | 0   |           | BOTTLES CHAINED TO POST   | 0              | 2  | 4   | 0    | 2      | ②        |               | PUT INTO AVAILABLE SPACE REGULATORS IN TRANSFORMER CASE             | FORSLIFT, RPIPE                                    | 20        |
| 3       | TANK, OIL STORAGE (ON SIDE)  | 1   | 12' 10'   | UNDER MEZZANINE FOR ELECTRIC LOAD                                       | 0              | 4  | 0   | 3    | 2      | 0        |               | DRAIN OIL FILL WITH WATER   |  | 25        |
| 4       | LOAD CENTER #3 SUBSTATION  | 1   | 3' 2' 15' | CENTER 20 X 15 X 12' ON MEZZANINE OVER OIL TANK                         | 0              | 2  | 4   | 2    | 2      | ②        |               | DISCONNECT LAST LOWER DOWN AND PUT INTO TRANSFORMER CASE IN DOCK    | 2 FORSLIFTS<br>HAND<br>TOOLS<br>CUTTING<br>TORCHES | 20        |
| 5       | JIB CRANES 1/2-AND 1-TON CAPACITY (SEE ITEM 3, PAGE 3)                   | 0   |           | MAY BE EASILY REMOVED FROM JIB  | 0              | 3  | 5   | 0    | 2      | 7        |               | REMOVE HOISTS LOWER INTO OPEN SPACES IN SAND BLAST PITS             | LADDERS<br>HAND<br>TOOLS                           | 20        |
| 6       | BUSWAYS (240V) BOTH SIDES OF BAY STRUNG BETWEEN COLUMN NEAR FT BUSH SIDE | 2   |           |   | 0              | 3  | 5   | 4    | 2      | 7        |               | REPLACE   |  |           |
| 7       | COIL WINDING MACHINE ON WHEELS SIZE OF LATHE APPROX 3' X 4' X 8'         | 0   |           | IN BAYS 5 THROUGH 8 LIGHT METAL ON WELDED FRAME WITH CONTROLLABLE MOTOR | 0              | 3  | 6   | 3    | 2      | 0        |               | PARTIALLY DISASSEMBLE LOAD INTO TRANSFORMER CASES IN BAYS 4 IN 6223 | HAND<br>TOOLS<br>ONLY                              | 25        |

DESCRIBE POSSIBLE COLLATERAL DAMAGE

RATING

PRIORITY = A+B or A+C (lowest sum)

THE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION IF DESIRED.

### Metal Stamping

This producer of large metal stampings is one of the largest such companies in the West, with well over 100 employees. There was no in-plant analysis here, in part because the plant is located only a few hundred feet from a tank farm storing over half a million gallons of flammables. Though this would be a factor in an actual hardening situation, it was of little concern in testing the manual for application to similar plants not so situated.

The SSI data collection and planning efforts at this plant took about 22 hours (copies of the SSI completed worksheets follow). The SSI analysis showed the vulnerability level (excluding the tank farm) could be raised 14 points, or from 2 psi to 16 psi, and could be completed at the end of the first day. The hardening methods applied in the analysis were removal of some items to host areas, and gang anchoring and cross brace welding used to provide stability and mutual protection for the very heavy stamping machines. These machines are very tall, tremendously massive, small-based units that would otherwise lack stability and likely be damaged by over-turning.

*(Text continues on p. 53)*

EQUIPMENT INVENTORY WORKSHEET # 1 PAGE

EQUIPMENT  
BOG SIDE BUILDING

PAGE  
I # 1  
SQUAD MEMBERS  
1. BOB  
2. KAMBERGER

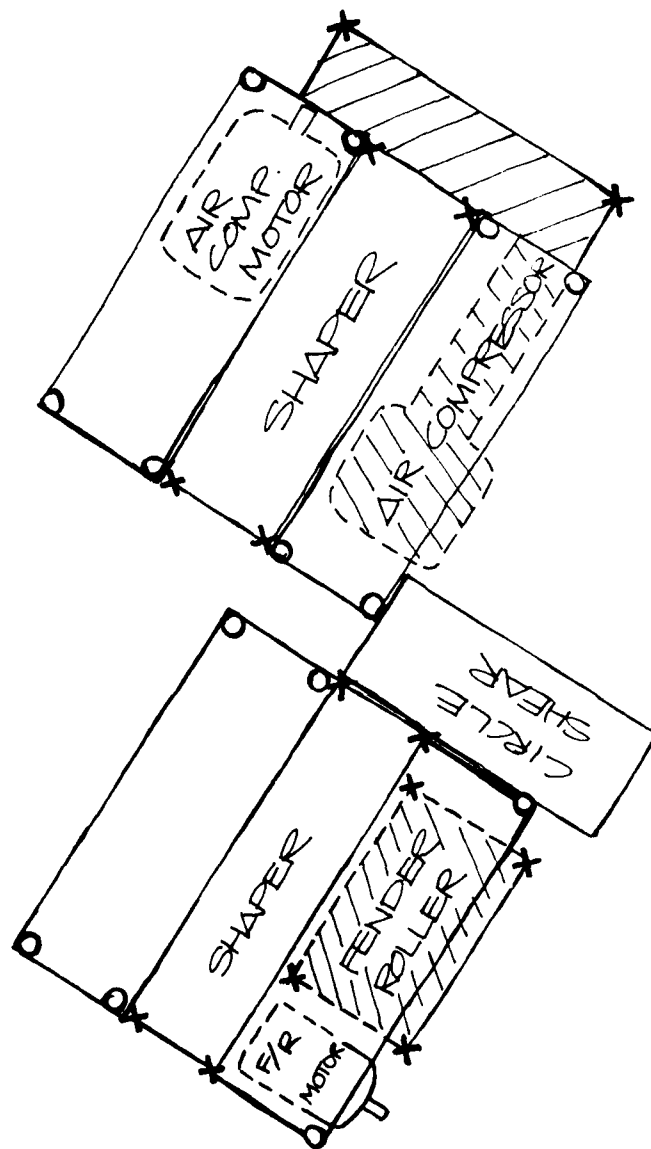
PAGE  
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| ITEM NO | EQUIPMENT NAME AND DESCRIPTION   | QTY | SIZE            | REMARKS  | START/STOP TIME | E | RR | E+R |   |   | STRUCTURAL | PRIORITY                            | EVALUATE                 |                          |  | HARDENING METHOD  | MATERIALS REQUIRED | TOTAL HOURS | TOTAL COST |
|---------|--|-----|-----------------|--|-----------------|---|----|-----|---|---|------------|-------------------------------------|--------------------------|--------------------------|--|---|--------------------|-------------|------------|
|         |  |     |                 |  |                 |   |    | B   | R | A |            |                                     | 1                        | 2                        | 3  |   |                    |             |            |
| 1       | NIAGARA CURTLE SHEAR   | 1   | 14' 2' 1' 0'    | 3/8" PLATE CONSTRUCTION BOLDED WITH 3/8" BOLTS (4 EACH)                | 0               | 3 | 2  | 5   | 5 | 2 | 7          | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | TIE TO BOTH CINCINNATI SHEARS (SEE SKETCH)   | LEVERS OF BCS CHANNEL WELDERS PERFLIFT                  | 1                  | 22          |            |
| 2       | CINCINNATI SHEAR (SHAPER) 480 V  | 2   | 14' 7' 10'      | VERY HEAVY CONSTRUCTION FOUR 3/4" BOLTS TO FLOOR                       | 0               | 3 | 2  | 5   | 5 | 2 | 7          | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | TIE TOGETHER AND WELDERS TO CIRCLE SHEAR (SEE SKETCH)                                      | HAND TOOLS WELDERS BAR AND BOARD STEEL CHANNEL PERFLIFT | 1                  | 22          |            |
| 3       | WAGNER (PRE-PAINTING) FIVE WATER HEATING STATIONS (GAS) NON-REMOL CONVEYOR TYPE (CONTINUOUS) | 1   | 14' 10' 10' 60' | WALLS 1/8" STEEL NOT FASTENED DOWN                                     | 0               | 3 | 2  | 5   | 2 | 2 | 7          | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | KNOCK DOWN FULL IRONS WITH WATER AND AFFIX TO FLOOR  | HAND TOOLS CUTTING TOOLS PERFLIFT                       | 1                  | 25          |            |
| 4       | PAINT SPRAY BOOTH THIN WALL  | 1   | 14' 8' 8' 6'    | 1/16" WALLS, NOT AFFIXED (CONCRETE)                                    | 0               | 4 | 4  | 8   | 2 | 2 | 10         | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | KNOCK DOWN   | HAND TOOLS CUTTING TOOLS PERFLIFT                       | 1                  | 25          |            |
| 5       | AIR COMPRESSOR (NOY 10 X 9) 450 RPM 60 HP  | 1   | 14' 8' 8' 6'    | VERTICAL, BOLTED TO HEAVY CONCRETE BASE, 1 FT HIGH WITH 3/8" BOLTS (4) | 0               | 2 | 2  | 4   | 5 | 2 | 10         | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | TAKE TO SHEDS (SHAPERS) AND TIE (WELD) TO ALL THREE  | HAND TOOLS LARGE PERFLIFT BED AND BAR STEEL             | 1                  | 22          |            |
| 6       | AIR RECEIVER   | 1   | 14' 10' 3'      | 3/8" WALLS. 5" INLET NOT FASTENED DOWN                                 | 0               | 3 | 1  | 4   | 0 | 2 | 10         | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | TAKE TO STORAGE YARD BETWEEN BLDGS. DIS HOLE AND BURST WITH 1 FT SHAPERS. FULL WITH WATER. | HAND TOOLS PERFLIFT                                     | 1                  | 34          |            |
| 7       | FENDER ROLLER  | 1   | 14' 5' 5'       | FOUR 1/2" BOLTS. HEAVY FRAME   | 0               | 2 | 3  | 5   | 5 | 2 | 7          | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | PUT WITH SHAPERS AND AIR COMPRESSOR IN SIDE BLDG EQUIPMENT "STAKE"                         | PERFLIFT HAND TOOLS PERFLIFT                            | 1                  | 25          |            |

DESCRIBE ROBBABLE COLLATERAL DAMAGE  
SHORT MEAS. POSSIBLE FROM WARD AND STREET WALLS AT BUILDING; HEAVY GASKES  
THICK METAL (STEEL AND ALUMINUM) IN FLOORS (UP TO 6 FT. HIGH)  
MOSTLY ALONG SOUTH WALL IN HIGH WARD, BUT INBOARD TOWARDS (TO PLIES OR STAKES)  
STAMPINGS THICKED UP TO 5 FT. HIGH WARD AND COME WITH PAINT LATE, THIN-  
WALLED ASSEMBLY THREATENS LIGHT EQUIPMENT  
GO BACK TO THIS WORKSHEET FOR THE PILES, WARNING EQUIPMENT, LOCATION IF DESIRED

PRIORITY = A+B or A+C (lowest sum)

RATING -



X = FASTENING POINTS  
TO FLOOR

# METAL STAMPING PLANT

PAGE # 2 HARDENING DECISION WORKSHEET

PAGE # 2 EQUIPMENT INVENTORY WORKSHEET

OLD SIDE BUILDING AREA

| NO. | EQUIPMENT NAME AND DESCRIPTION  | QTY | SIZE     | REMARKS                                      | SHIFT DOWN TIME | E | R | STRENGTH | PRIORITY | INVERT | HARDENING METHOD  | MATERIALS REQUIRED                             | TO BE EVALUATED | TO BE EVALUATED |
|-----|---|-----|----------|--|-----------------|---|---|----------|----------|--------|---|--|-----------------|-----------------|
| 1   | TRUCK AND STAMP TABLE WITH DIES AND PATTERN CYLINDER (24 10-IN. DIAMETER CYLINDERS) | 1   | 3' 4' 8' | 1-IN. THICK TABLE TOP NOT AFFIXED VERY HEAVY | 0               | 4 | 2 | 0        | 2        | 0      | INVERT. PLACE NEXT TO CONCRETE CURB                                   | FORKLIFT + HAND TOOLS                          | 50              | 50              |
| 2   | WELDING AREA WITH PORTABLE WELDERS (MIG)  | 3   | 3' 2' 5' | SMALL WELDERS AND TABLES                     | 0               | 2 | 2 | 4        | 4        | 0      | EVALUATE WELDERS INVERT TABLES DO LAST!                               | FORKLIFTS TRUCK RAMP                           | 100             | 100             |
| 3   | WATER TEST (DIP) TANK FOR TESTING RADIATORS   | 1   | 3' 3' 0' | NOT AFFIXED                                  | 0               | 2 | 4 | 0        | 2        | 0      | LEAVE FULL AFFIX TO FLOOR   | EQUIPMENT ANCHORS ELECTRICAL SUPPLY HAND TOOLS | N/A             | 25              |
| 4   | CONTINUOUS FLOW WELDERS ON AGRAS BOTTOM PLATE 18' SQUARE                            | 4   | 0' 4' 0' | WITH FOUR 1/2-IN. BARS                       | 0               | 4 | 3 | 7        | 3        | 2      | UNBOLT AND EVALUATE   | SMALL FORKLIFT TRUCK HAND TOOLS                | 25              | 25              |
| 5   | 4000-LB CAPACITY FORKLIFT   | 2   | 0' 4' 0' | SOLID-TIRED, LPG-POWERED HANDLES             | 0               | 2 | 3 | 5        | 0        | 2      | PUT ON TRUCK LAST AND EVALUATE WITH PATTERNS AND DIES DO LAST!        | RAMP TO TRUCK                                  | 100             | 100             |
| 6   | DIES AND PATTERNS   |     |          |  |                 |   |   |          |          |        | PUT ONE IN EACH PRESS AND CLOSE EVALUATE ALL OTHERS                   |  |                 |                 |
| 7   | MATERIAL SICKLES  |     |          |  |                 |   |   |          |          |        | BAND TOGETHER, LIE FLAT, SOME STICKS PLACED BETWEEN PLATES OF PRESSES |  |                 |                 |

DESCRIBE POSSIBLE COLLATERAL DAMAGE  
STICKS OF FINISHED RADIATORS, BUMPEES AND FENDERS NEAR MACHINES, SOME IN OPEN, SLATTED CRATES, SOME ON PALLETS

PRIORITY = A+B or A+C (lowest sum)

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED

SSI ANALYSIS

### Steel Fabrication Plant

This is a modest plant in the steel fabrication and erection business that employs 25 to 30 people. The hardening assessment conducted at this plant was entirely by SSI personnel (see the following copies of the work-sheets). This planning effort took approximately 32 hours. The lowest Priority before hardening was 6, and the lowest New Rating became 14, for an 8 point, 8 psi, overall improvement in plant vulnerability. The hardening strategy was to move small power and hand tools to host areas and gang anchor and cross brace heavier equipment in stable arrays using steel members and welding equipment on hand. The hardening effort was estimated to be completed by the end of the first day.

*(Text continues on p. 63)*



## STEEL FABRICATION

## HARDENING DECISION WORKSHEET

PAGE # 1

PAGE # 1

## EQUIPMENT INVENTORY WORKSHEET

BLOG MAIN BAY

AREA

SQUAD NUMBER

SQUAD NUMBER

| ITEM NO | EQUIPMENT NAME AND DESCRIPTION     | QTY | SIZE      | REMARKS   | SHUT DOWN TIME | RR | E | RR | BLAST | STRUCTURE | PRIORITY | CONCRETE | REINFORCING | STEEL | NEW | MATERIALS REQUIRED   | HARDENING METHOD   | NOTES |
|---------|------------------------------------|-----|-----------|---|----------------|----|---|----|-------|-----------|----------|----------|-------------|-------|-----|--|--|-------|
| 1       | ANGLE SHEAR/ SURFICIAL IRON NUMBER | 1   | 7' 2' 6"  | FOUR 1/2-IN. BOLTS TO CONCRETE FLOR VERY HEAVY CONSTRUCTION | 0              | 3  | 2 | 2  | 5     | 5         | 2        | 7        |             |       |     | BRIDGE CRANE HAND REMOVED AND AFFIXED UNDERBATH TOOLS WELDER | OTHER EQUIPMENT TO BE AFFIXED TO THIS ITEM. MOTOR REMOVED AND AFFIXED UNDERBATH TOOLS WELDER | W15   |
| 2       | CINCINNATI/ CENTURY SHEAR          | 1   | 7' 12' 4" | 1/2-IN. BOLTS TO CONCRETE (MORE THAN 10)                    | 0              | 2  | 2 | 2  | 4     | 5         | 2        | 6        |             |       |     | BRIDGE CRANE HAND REMOVED AND AFFIXED UNDERBATH TOOLS WELDER | OTHER EQUIPMENT TO BE AFFIXED TO THIS ITEM. MOTOR REMOVED AND AFFIXED UNDERBATH TOOLS WELDER | W15   |
| 3       | CUTTING TABLE - 1/2" X 4' ON EDGE  | 1   | 3' 0' 30" | NOT AFFIXED   | 0              | 4  | 4 | 4  | 6     | 2         | 10       |          |             |       |     | HOIST CRANE  | INVERT AND AFFIX TO REAR UNDER SHEAR TABLE   | W15   |
| 4       | VERTICAL BORING MACHINE            | 1   | 8' 3' 7"  | NOT AFFIXED; HEAVY BASE                                     | 0              | 3  | 2 | 2  | 5     | 5         | 2        | 7        |             |       |     | WELDER BAR STOCK (ANCHORS) 1/2-IN. BOLTS                     | LOWER CENTER OF GRAVITY AND WELD OR TIE TO CINCINNATI SHEAR                                  | W15   |
| 5       | SMALL SAND BLASTER (SAND TANK)     | 1   | 4' 2'     | BROKABLE; ON 18-IN. WHEELS                                  | 0              | 3  | 3 | 3  | 6     | 5         | 2        | 9        |             |       |     | NONE   | EVALUATE WITH COMPANY TRUCK  | W15   |
| 6       | THREADING MACHINE 3 HP             | 1   | 5' 2' 5"  | FOUR 1/2-IN. BOLTS TOP HEAVY NOT AFFIXED                    | 0              | 3  | 2 | 2  | 5     | 5         | 2        | 7        |             |       |     | BRIDGE CRANE CHAIN   | EVALUATE WITH COMPANY TRUCK  | W15   |
| 7       | SMALL CUTOFF SAW                   | 1   | 4' 2' 3"  | LIGHT; NOT AFFIXED  | 0              | 3  | 3 | 3  | 6     | 6         | 2        | 9        |             |       |     | BRIDGE CRANE CHAIN   | EVALUATE WITH COMPANY TRUCK  | W15   |

PRIORITY = A+B or A+C (lowest sum)

DESCRIBE POSSIBLE COLLATERAL DAMAGE

COLLATERAL DAMAGE POSSIBLE FROM STIZED SUPPLIES INCLUDING I BEAMS, PLATE, ROUNDS, ETC.

BACK BUILDING ACROSS STREET (TO THE WEST)

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED

STEEL FABRICATION

EQUIPMENT INVENTORY WORKSHEET # 2 PAGE 2 HARDENING DECISION WORKSHEET

BLDG MAIN BAY AREA SQUAD MEMBERS

| ITEM NO | EQUIPMENT NAME AND DESCRIPTION  | QTY | SIZE         | REMARKS                                       | SAFETY DANGER TIME | E | OR | E+R | BLAST | STRUCTURE | PRIORITY | ROCKET                              | EXPLOSION                           | HARDENING METHOD  | MATERIALS REQUIRED                                    | NOTES |
|---------|---------------------------------|-----|--------------|---|--------------------|---|----|-----|-------|-----------|----------|-------------------------------------|-------------------------------------|---|---|-------|
| 1       | DOUBLE ENDED PUNCH              | 1   | 1' 0" 4' 10" | VERY HEAVY LASTERING WITH EIGHT 1/2" IN BOLTS | 0                  | 3 | 3  | 6   | 5     | 2         | 0        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | TO HAVE OTHER ITEM ATTACHED AND AFFIXED TO COLUMN FOOTINGS                                    | BRIDGE CRANE WELDERS HAND TOOLS                       | 10    |
| 2       | PUNCH PRESS                     | 1   | 6' 3' 3'     | VERY TOPHEAVY; NOT AFFIXED                    | 0                  | 3 | 3  | 6   | 5     | 2         | 0        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | CHANGE CENTER OF GRAVITY, ATTACH AND SECURE TO RANCH  | BRIDGE CRANE WELDERS HAND TOOLS                       | 10    |
| 3       | CUT OFF SAW 21 IN BLADE         | 1   | 5' 4' 0"     | TOPHEAVY; NOT AFFIXED                         | 0                  | 3 | 3  | 6   | 5     | 2         | 0        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | EVALUATE  | BRIDGE CRANE TALK                                     | 10    |
| 4       | BENDING TABLE                   | 1   | 4' 2' 3'     | TOPHEAVY; NOT AFFIXED                         | 0                  | 3 | 3  | 6   | 5     | 2         | 0        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | EVALUATE  | BRIDGE CRANE TRUCK                                    | 10    |
| 5       | IDEAL ARC TM 500 WELDERS        | 4   | 3' 2' 3'     | NOT AFFIXED                                   | 0                  | 2 | 2  | 4   | 2     | 2         | 0        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | EVALUATE  | BRIDGE CRANE TRUCK                                    | 10    |
| 6       | M-G SETS (WELDERS, D.C.)        | 3   | 3' 2' 10"    | NOT AFFIXED                                   | 0                  | 3 | 2  | 5   | 3     | 2         | 7        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | EVALUATE IF BEAM ON TRUCK AND IF TIME PERMITS PLACE OTHERWISE PLACE ON FLOOR AND TIE TOGETHER | USE THESE TO WELD RAIL AROUND MAKE STEEL BOX TIE DOWN | 20    |
| 7       | I/R AIR COMPRESSOR - HORIZONTAL | 1   | 4' 4' 10"    | SIX OR EIGHT 1/2" BOLTS                       | 0                  | 2 | 2  | 4   | 5     | 2         | 0        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | REMOVE MOTOR AND FLYWHEEL BELTS & CLAMPED FASTEN TO RAIL WITH ADDITIONAL SAND BAGS            | HAND TOOLS EQUIPMENT ANCHORS                          | 10    |

DESCRIBE POSSIBLE COLLATERAL DAMAGE COLLATERAL DAMAGE: LIKELY FROM RACKS AND PILES OF STEEL SUPPLIES (ANGLES, BARS, BUNDLES, FLAT, FLAT STACK, ETC.)

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED

PRIORITY = A+B or A+C (lowest sum)

RATING

STEEL FABRICATION

EQUIPMENT INVENTORY WORKSHEET # 3 PAGE 3  
 AREA SIDE BAY SQUAD MEMBERS

HARDENING DECISION WORKSHEET

| ITEM NO. | EQUIPMENT NAME AND DESCRIPTION  | QTY | SIZE            | REMARKS  | START/STOP TIME         | E+R | BLAST | STRUCTURE | PRIORITY | PROTECTIVE WORKSHEETING | HARDENING METHOD   | MATERIALS REQUIRED                         | HOST AREA |
|----------|---|-----|-----------------|--|-------------------------|-----|-------|-----------|----------|-------------------------|--|--|-----------|
| 1        | BRIDGE CRANE, ELECTRIC<br>5-TON, 40-FT. SPAN                                    | 1   | 11' x 21' x 1'  | ON STEEL BEAMS DOWN CENTER OF BAY WIDE-FLANGED BEAMS ON WOODEN POSTS | 0 3 2                   | 5   | 6     | 2         | 7        |                         | DROP TO GROUND WELD BRIDGE ACROSS STRUCTURAL COLUMNS AT GROUND LEVEL. EVALUATE HOST                  | SAVE UNTIL LAST                            | TH-1      |
| 2        | ONE-TON HOIST ON MONORAIL   | 3   | 11' x 21' x 1'  | HELD WITH ONE 3/4" BOLT TO TROLLEY                                   | 0 3 2                   | 5   | 6     | 2         | 7        |                         | EVALUATE WITH COMPANY TRUCK  | HAND TOOLS HAND TRUCK CART                 | TH-2      |
| 3        | HYDRAULIC POWER KIT FOR TOOLS AND ATTACHMENTS                                   | 1   | 2' x 3' x 2'    | HEAVY DUTY PUMPS, FRAME AND OIL STORAGE TANK SHED-MOUNTED/PORABLE    | 0 3 2                   | 5   | 6     | 2         | 7        |                         | EVALUATE WITH COMPANY TRUCK  | HAND TRUCK CART                            | TH-3      |
| 4        | WELD PUNCH (HYDRAULIC) FOR USE WITH ABOVE                                       | 1   | 18" x 12" x 12" | VERY HEAVY FRAME PORTABLE  | 0 3 2                   | 5   | 6     | 2         | 7        |                         | EVALUATE WITH COMPANY TRUCK  | HAND TRUCK CART                            | TH-4      |
| 5        | SMALL DRILL PRESS   | 1   | 11' x 5' x 2'   | MOVABLE, NOT AFFIXED   | 0 3 2                   | 5   | 4     | 2         | 7        |                         | EVALUATE WITH COMPANY TRUCK  | HAND TRUCK CART                            | TH-5      |
| 6        | WELD PUNCH (LARGE)  | 1   | 11' x 5' x 2'   | MOVABLE, NOT AFFIXED   | 0 3 2                   | 5   | 6     | 2         | 7        |                         | EVALUATE WITH COMPANY TRUCK  | HAND TRUCK CART                            | TH-6      |
| 7        | BACKS FULL OF STEEL STOCK WIDE FLANGES, ANGLES, FLATS, ROUNDS, CHANNELS, PLATES | 1   | 11' x 21' x 1'  | SOME BUNDLED TOGETHER; OTHERS LOOSE IN RACKS                         | PROTECTIVE HOUSEKEEPING |     |       |           |          |                         | MOST TO BE TIED TOGETHER AND PUT ON FLOOR. SOME TO BE EVALUATED FOR USE IN THE FUTURE (CONSTRUCTION) | BRIDGE BEAMS, HOISTS, WELDER BANDING TOOLS | TH-7      |

--- RATING ---

PRIORITY = A+B or A+C (lowest sum)

DESCRIBE POSSIBLE COLLATERAL DAMAGE

SITUATED IN OPEN-ENDED, STEEL-FRAMED STRUCTURE WITH ONE OPEN SIDE (OTHER SIDE AGAINST WOODEN WALL OF MAIN BAY).

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED

# STEEL FABRICATION

## RESOURCE INVENTORY FORM

TYPE Steel TEAM # 1 SHEET # 1 AREA plant

TIME: START 2:30 FINISH 2:45 CHECKED \_\_\_\_\_

| NUMBER | DESCRIPTION OF ITEM  | Location | QUANTITY | PRE | POST |
|--------|--|----------|----------|-----|------|
| 1      | Welders  | various  | 8        | ✓   |      |
| 2      | Torches  | various  | 4        | ✓   |      |
| 3      | Use steel members to build frames around machines to protect from building collapse. |          |          |     |      |
| 4      |  |          |          |     |      |
| 5      |  |          |          |     |      |
| 6      |  |          |          |     |      |
| 7      |  |          |          |     |      |
| 8      |  |          |          |     |      |
| 9      |  |          |          |     |      |
| 10     |  |          |          |     |      |

SSI ANALYSIS

### Food Processor

Two food processing plants provided pertinent information on industrial preparedness, though not of the sort expected. One plant was a packager and exporter of dried fruits, the other was a large canner of tomato products, and each had several hundred employees. Figures 10 and 11 show pictures taken at the canning plant. No data sheets were completed for reasons that will become apparent.

At all plants, eventually, there arises the question what equipment the plant could do without in a serious emergency. The initial answer is generally about the same, "Nothing can be done without" - - - "We need all of it, that's why we have it."

To cut through this inertia takes about a half hour of serious discussion to set the scene regarding what conditions might be like after a nuclear attack. For the few who rebel at this thought altogether, discussion remains fixed on natural disasters such as earthquakes, hurricanes, tornadoes, and the great similarities in damage (just not quite so widespread). Most begin to get the circumstances pictured well enough eventually to see alternatives. At both food processing plants the answer changed to "We don't need any of it [the plant and the equipment]." In one case this was because all the important processing [fruit drying] takes place near where it is grown, and the fruit is shipped to the plant for packaging only. At the second plant (see Appendix A for the detailed exchange) a similar type of response was made — but in this case there was an immediate realization that equipment could be converted to pasteurize milk or to process meat. This would require saving only a steam source, the cooker, and the canner, which would not take a great deal of manpower or time.

*(Text continues on p. 67)*

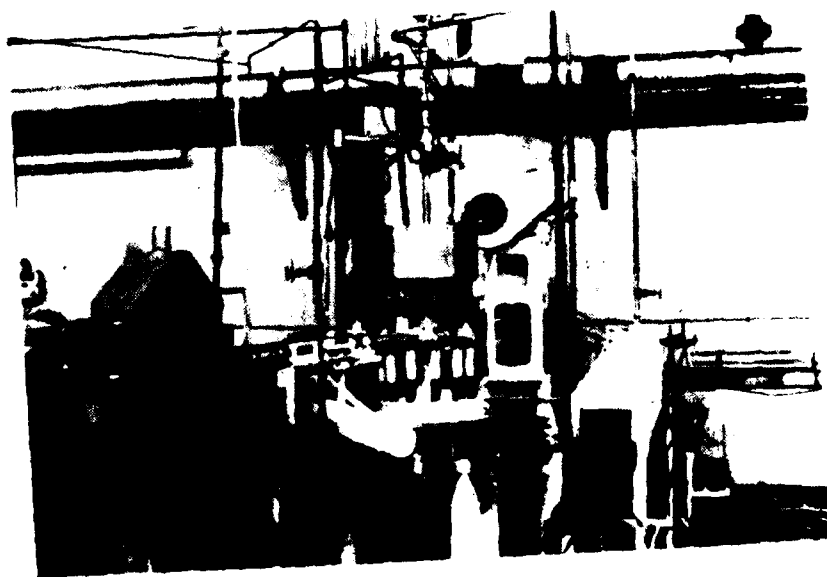
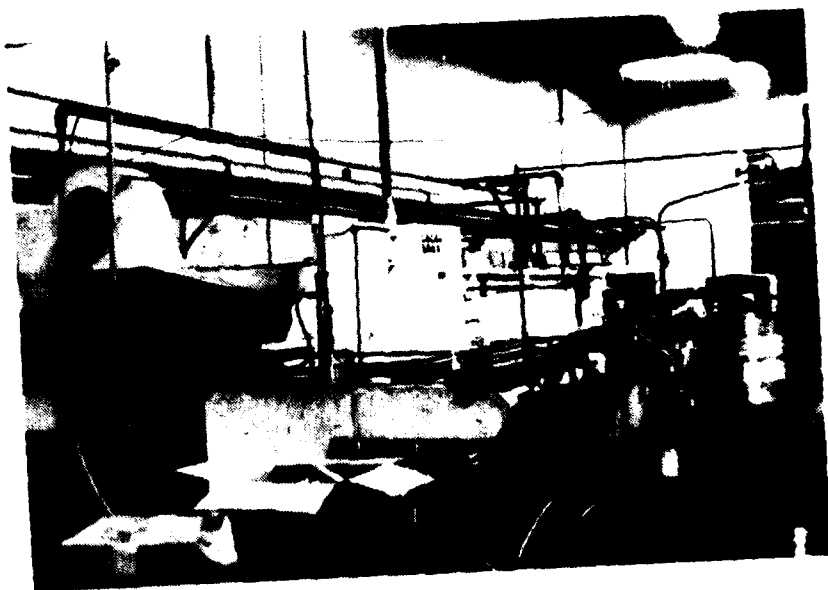


Fig. 10. Food Canning Plant.

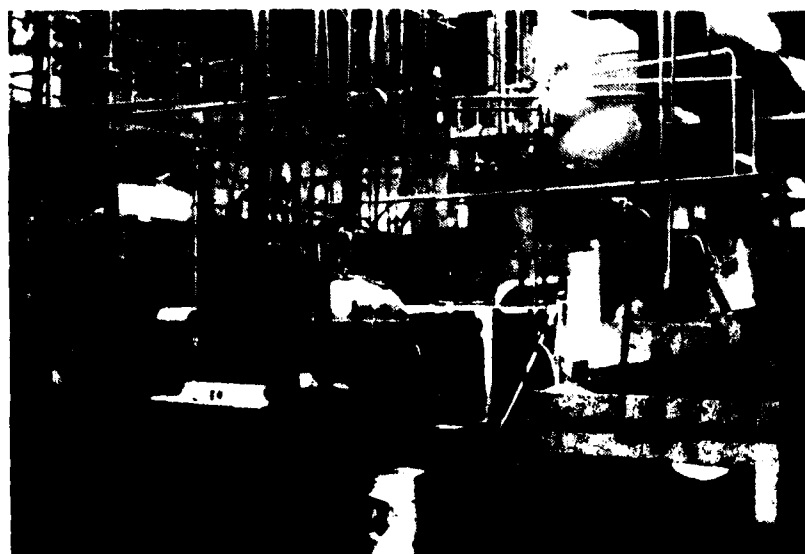
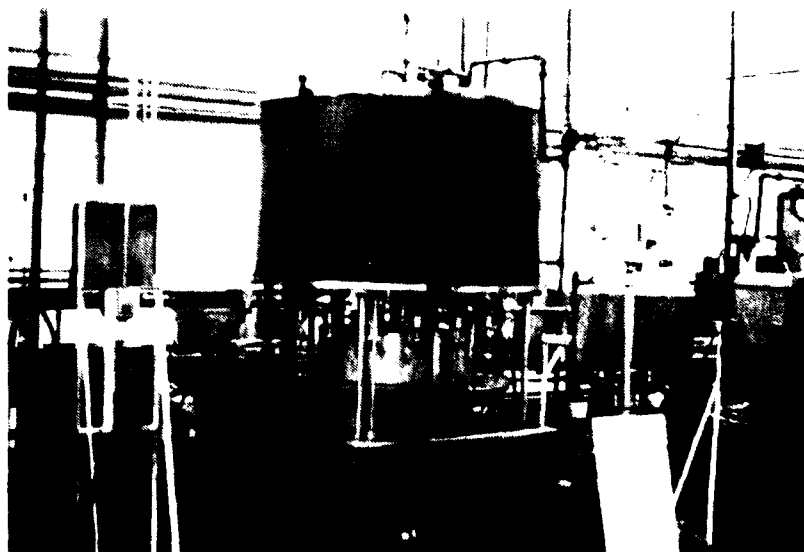


Fig. 11. Food Canning Plant.

### Utility

This was a large water utility serving several million people. Though no data sheets were completed by either SSI or plant personnel, two utility representatives read most of the booklets and met with SSI personnel to discuss the manual. By its nature, this particular utility is already well dispersed. In many locations in the region it serves, the water supply is from underground wells that are tapped by local pumps, electrically powered. For emergency situations, when power is unavailable, a number of gasoline-powered mobile units with diesel-powered pumps are maintained, which could be dispatched to critical areas, post-attack.

The utility's reviewers did not believe a self-help plan for hardening applicable in their case, though they concurred that early planning and last minute action were most probable modes of response. The hardening and relocation aspects did not seem practical in view of the fact that the company is already largely decentralized with a significant portion of the water supply coming from widely dispersed wells. Moreover, they didn't believe more than one or two individuals capable of effective response would report when it was finally and obviously time for last minute action.

The reviewers provided two recommendations, based on their particular situation. Some means for an effective public communication system to locate their competent, experienced personnel, post-attack, for recovery operations, would be the most valuable part of any company plan. And, assurance of a long-term fuel supply to operate the emergency units would be required because their disaster scenarios are based on short-term emergencies.



## PHASE II — HARDENING EXERCISES

For this program element, four hardening exercises were conducted on-site, and empirical data on time, manpower, materials, and techniques applied were obtained for comparison with analytical data. Slides and movies were made for presentations. These onsite demonstration exercises covered the three major types of preparedness protection — harden-in-place, evacuate, and relocate nearby and harden. The first type of hardening exercise was conducted at one plant by SSI personnel, and the other two types were conducted entirely by industry personnel at the plants involved.

### Harden-In-Place Demonstration

As noted in the Phase I section of this report, there are a number of activities associated with the harden-in-place alternative. For example, these include: the management decision to use such factors as size and vulnerability of equipment, type of structure in which equipment is located, whether the industry is essential and must be kept operating as long as possible, etc.; a screening process to determine which equipment and processes are essential and must be protected; a resource inventory to determine the types of hardening alternatives that can be used; and the protective housekeeping phase of industrial protection. Under protective housekeeping a number of activities are performed, such as: protection of vital records; removal of flammable materials; unhooking power and fuel lines; removing or covering vulnerable gauges, controls, handles, etc.; and many other simple activities that greatly reduce the vulnerability of equipment and structures to blast, fire, and EMP.

The particular plant available for the harden-in-place exercise was a wood products plant located in Cloverdale, California. This plant is several acres in extent with well over an acre of buildings. The project

team was permitted relatively unlimited access to the facility during a month-long shutdown period. The machines located in the plant were, of course, associated with various woodcutting and shaping activities, but were also of a size and weight typical of a wide variety of machine tools used for other manufacturing processes. Overall views of the facility and some of the typical equipment are shown in Figures 12 through 17.

As in the Phase I analyses, the hardening procedures conducted have included an essential-equipment selection process, determination of the protective housekeeping measures applicable to the plant and to each piece of equipment, and estimates of time in man-hours to complete each task. These are summarized in the attached data sheets completed by SSI personnel. The assessment took only a few hours, and the expected improvement in vulnerability rating was 18 points, corresponding to a jump from 2 psi to 20 psi.

Since the primary damage parameter for most of the essential equipment would be collapse of the relatively weak, but also relatively light, wooden structures, the primary hardening measure used was to cover the machines with sandbags, as shown in Figures 18 through 25. Figures 18 through 21 show the sandbagging sequence for a planer and Figures 22 through 25, a similar sequence for a joiner. With regard to the planer it will be noted that a number of sheet metal pipes, which are used for dust collectors, remain in view. These, of course, would be removed during the actual hardening process, but to avoid damage to the equipment they were not removed for this demonstration. It was also determined that this relatively light sandbag covering would protect the equipment from building collapse and, if necessary, fire. To protect the machines, individually, would require 25,000 sandbags — or heavy plastic sheet, an end-loader, and several hundred yards of sand or dirt.

It was interesting to note in this plant that almost all the heavy equipment was skid-mounted and not affixed securely to the floor (see, for example, Figures 14 and 22). This has been noted in many plants where

equipment is either lightly fastened to the floor or not fastened at all. This points up the fact that in-place hardening will in many cases require the more secure fastening of equipment to the floor (probably during the protective housekeeping operation). However, it also facilitates an effective alternative. Where equipment is not bolted down, and particularly where it is skid-mounted, rapid movement of many items of equipment out of the structure is possible. To demonstrate this, the joiner used in the previous demonstration was moved into an open area near the plant and hardened using stacks of lumber (readily available), sandbags, and cable tiedowns. This procedure is shown in Figures 26 through 28.

If all the important equipment were skidded out of the plant structure, gathered in a clump, and sandbagged, the number of sandbags required would be reduced by half or more, and so would the time required for hardening. Moreover, bolting might prove totally unnecessary in this case. For example, Figures 29 through 32, compared with Figures 33 through 36, provide a simple graphic summary of the change in stability and in quantities of sandbags required when the horizontal dimension of the array is made large relative to the vertical dimension. The more stable configuration is also considerably easier to stack sandbags around.

*(Text continues on p. 87)*



Fig. 12. View Outside One End of the Wood Products Plant.



Fig. 13. View Inside the End Building Visible in Figure 12.

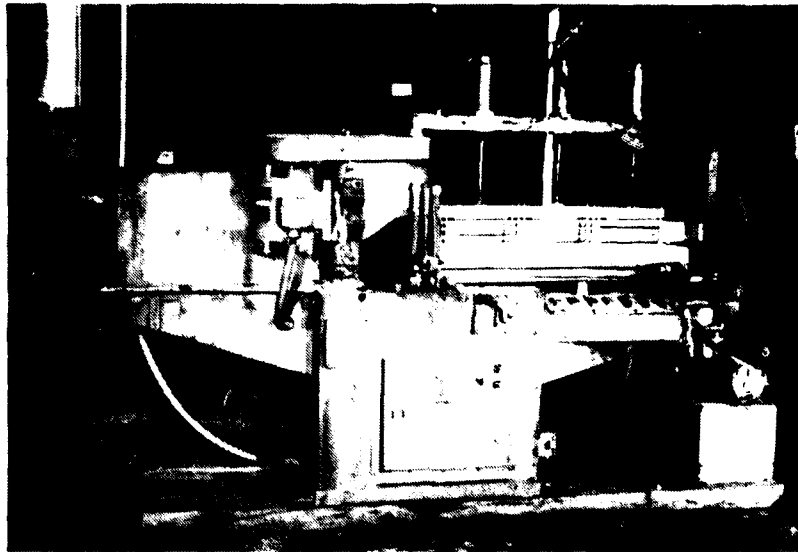


Fig. 14. Skid-Mounted 48-inch Twin Spindle Profile Shaper.

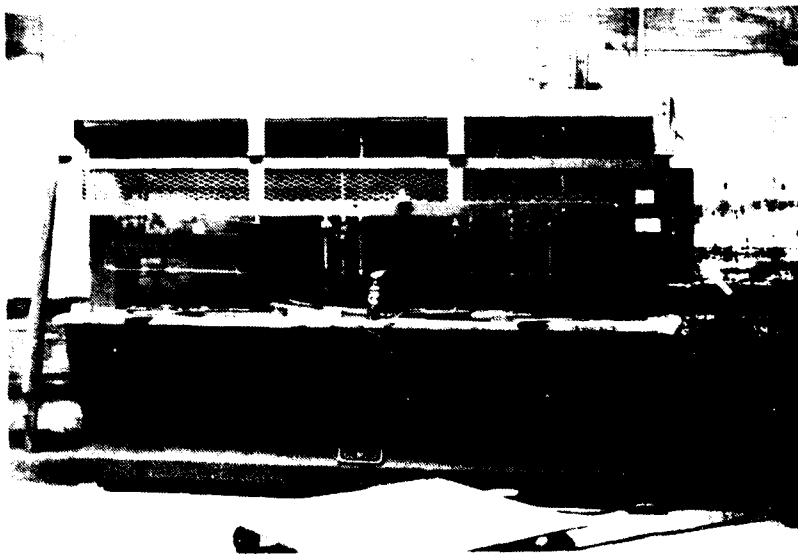


Fig. 15. CEMCO Multiple Drill.

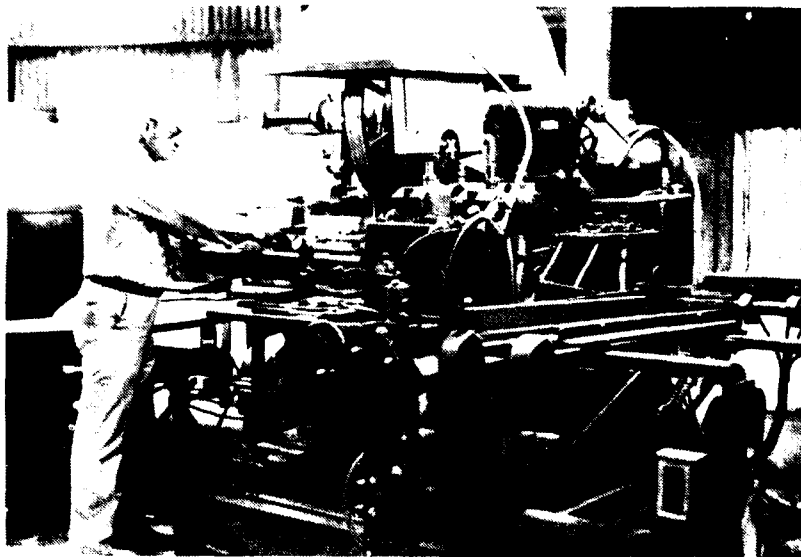


Fig. 16. Twin Band Mershon Resaw.

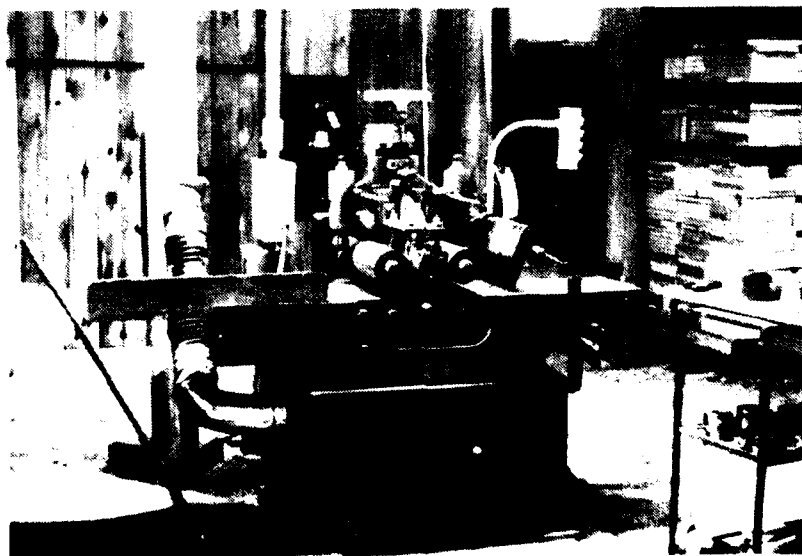


Fig. 17. Moulder.



Fig. 18. Yates Moulder.

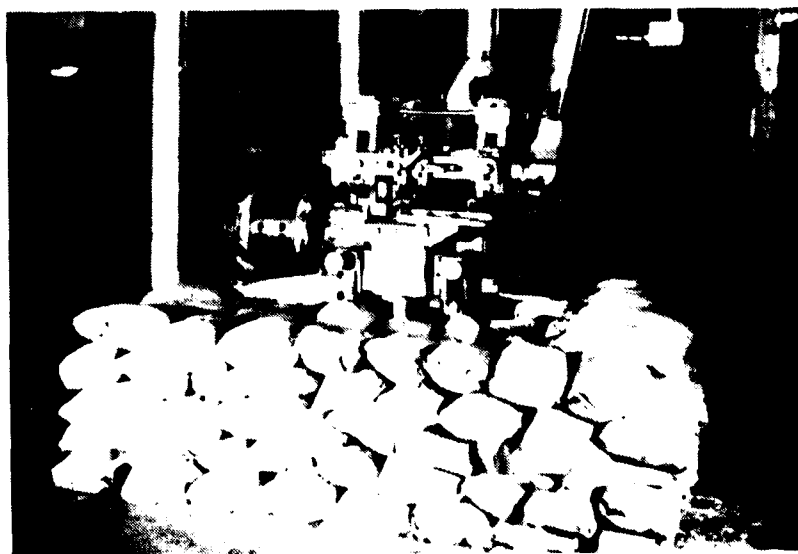


Fig. 19. Yates Moulder at First Stage of Hardening.



Fig. 20. Moulder at Two-Thirds Stage of Hardening.



Fig. 21. Moulder Completely Hardened.



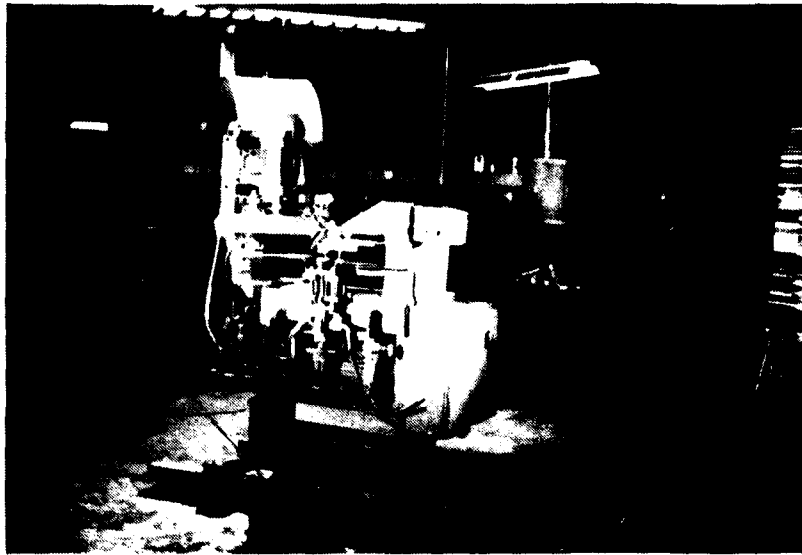


Fig. 22. Joiner Before Hardening.

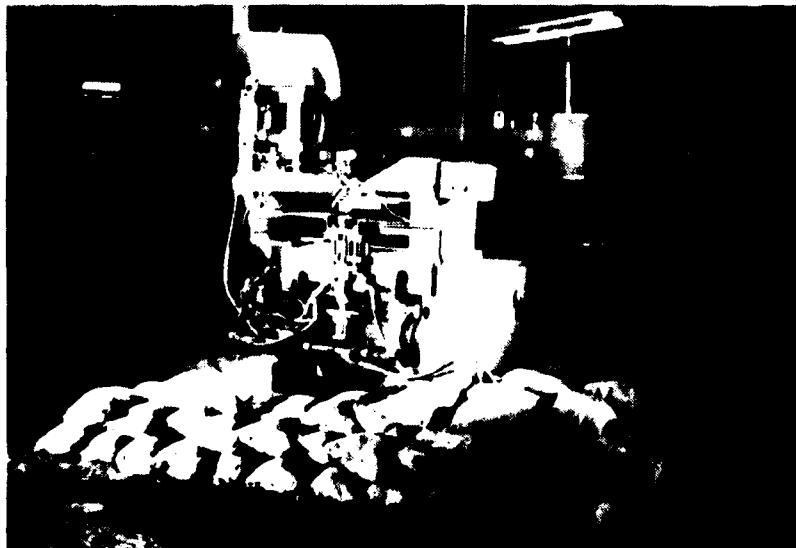


Fig. 23. Joiner With Beginning Layer of Sandbags.

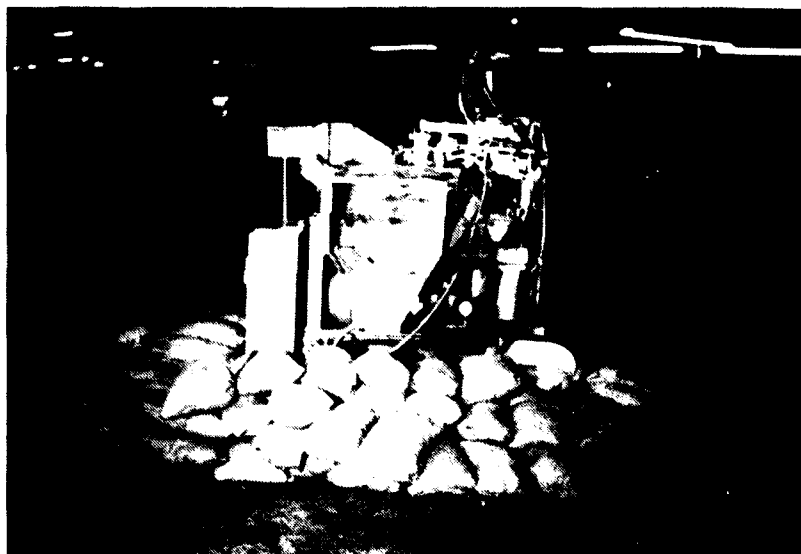


Fig. 24. Joiner, View from Opposite Side.



Fig. 25. Joiner Completely Covered.



Fig. 26. Joiner Moved Outside With Stacks of Wood Placed On Either Side.



Fig. 27. Joiner Partially Covered With Sandbags.



Fig. 28. Joiner Hardening Completed.

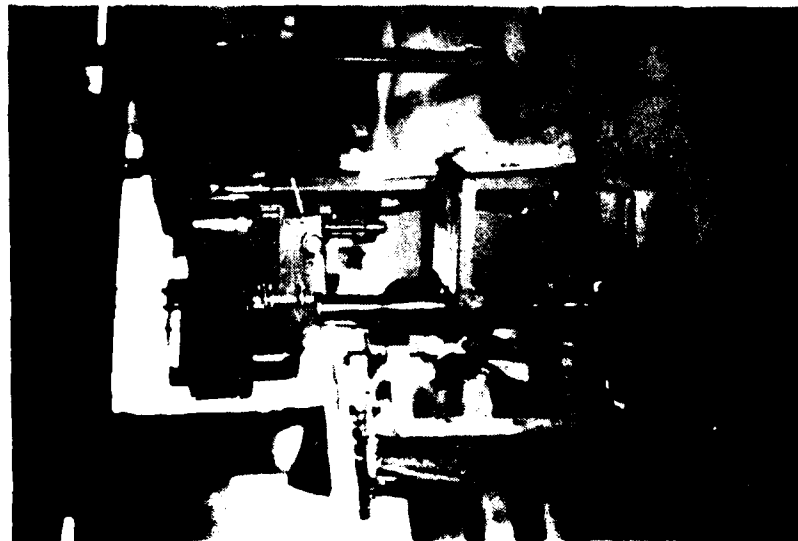


Fig. 29. Fixed Drill Press — Operating Position

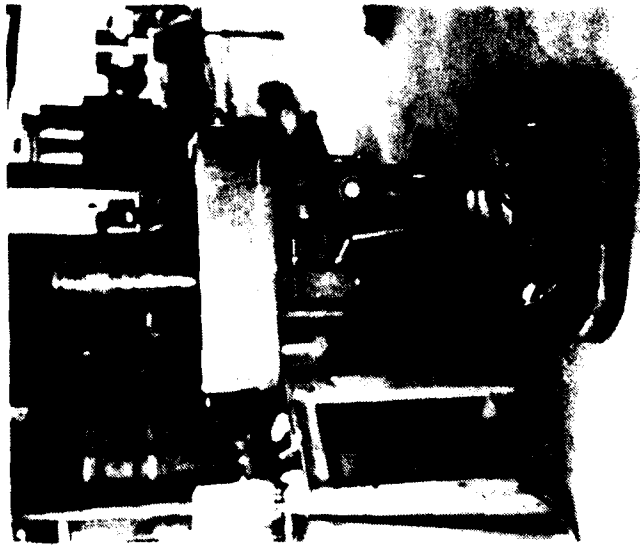


Fig. 30. Fixed Drill Press — Center of Gravity Minimized.

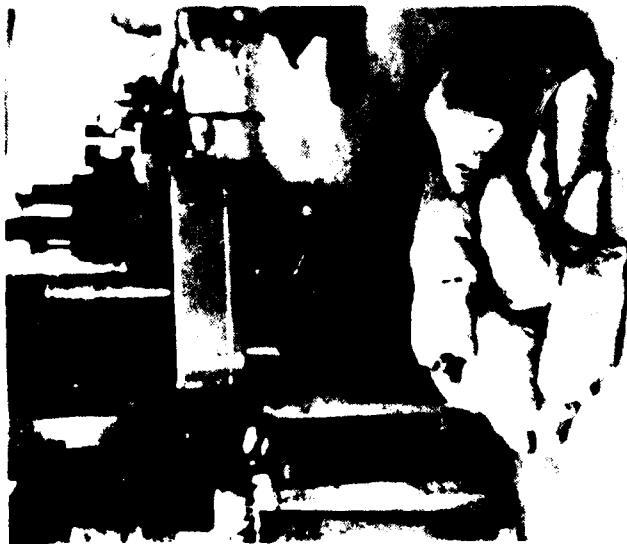


Fig. 31. Fixed Drill Press — First Stage of Hardening.

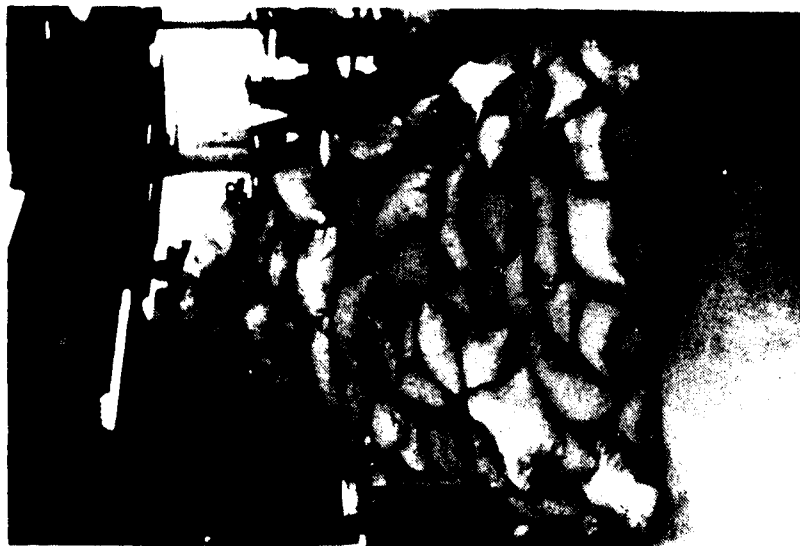


Fig. 32. Fixed Drill Press — Hardened.

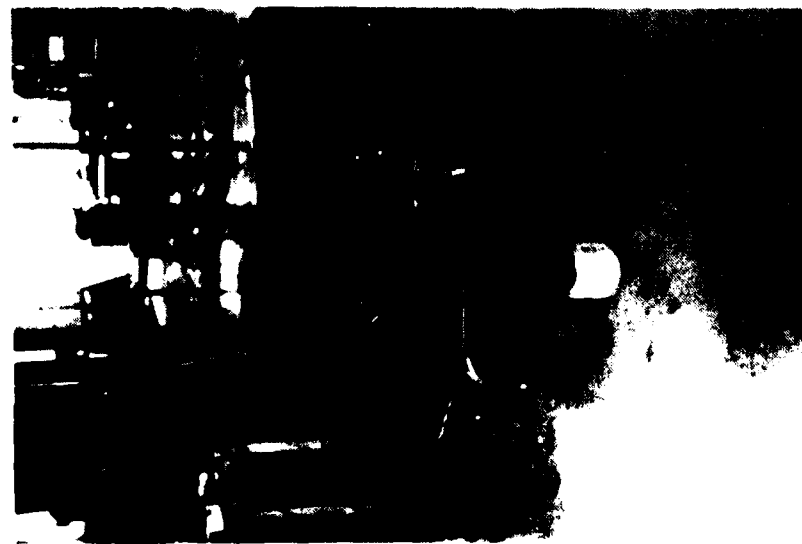


Fig. 33. Free Drill Press - Center of Gravity Optimized.



Fig. 34. Free Drill Press - First Stage of Hardening.



Fig. 35. Free Drill Press — Second Stage of Hardening.



Fig. 36. Free Drill Press — Hardened.



## # 1 HARDENING DECISION WORKSHEET

PUG. EAST \_\_\_\_\_  
EQUIPMENT INVENTORY WORKSHEET # \_\_\_\_\_  
SERIAL MEMBERS JOHN

PUG. EAST \_\_\_\_\_  
EQUIPMENT INVENTORY WORKSHEET # \_\_\_\_\_  
SERIAL MEMBERS JOHN

| INVENTORY NO. | EQUIPMENT NAME AND DESCRIPTION | QTY | SIZE | REMARKS                       | SHOT DOWN TIME | E | R | FLOOR |   |   |   | PLAST | SPURGE | PRIORITY | PROJECT | WORK IN PROGRESS | CUMULATIVE | HARDENING METHOD      | MATERIALS REQUIRED              | MATERIALS USED  | DATE |
|---------------|--------------------------------|-----|------|-------------------------------|----------------|---|---|-------|---|---|---|-------|--------|----------|---------|------------------|------------|-----------------------|---------------------------------|-----------------|------|
|               |                                |     |      |                               |                |   |   | 1     | 2 | 3 | 4 |       |        |          |         |                  |            |                       |                                 |                 |      |
| 1             | RESAW                          | 2   | 1/2" | ON SKIDS                      | 0              |   |   | 2     | 3 | 2 | 4 |       |        |          |         |                  |            | BOLT TO FLOOR SANDBAG | CONCRETE DRILL ANCHORS SANDBAGS | TH 24 MEN TA 23 |      |
| 2             | MULTIPLE DRILL                 | 1   | 1/2" | LOOSELY TIED WITH SMALL BOLTS | 0              |   |   | 2     | 2 | 2 | 4 |       |        |          |         |                  |            | BOLT TO FLOOR SANDBAG | CONCRETE DRILL ANCHORS SANDBAGS | TH 12 MEN TA 22 |      |
| 3             | TENSIONER                      | 4   | 1/2" | ON SKIDS                      | 0              |   |   | 2     | 3 | 2 | 4 |       |        |          |         |                  |            | BOLT TO FLOOR SANDBAG | CONCRETE DRILL ANCHORS SANDBAGS | TH 24 MEN TA 23 |      |
| 4             | WALKER                         | 2   | 1/2" | BOLTED, SMALL                 | 0              |   |   |       |   | 2 | 3 | 2     | 4      |          |         |                  |            | BOLT TO FLOOR SANDBAG | CONCRETE DRILL ANCHORS SANDBAGS | TH 24 MEN TA 23 |      |
| 5             | RESAW                          | 1   | 1/2" | BOLTED, SMALL                 | 0              |   |   | 2     | 2 | 2 | 4 |       |        |          |         |                  |            | BOLT TO FLOOR SANDBAG | CONCRETE DRILL ANCHORS SANDBAGS | TH 12 MEN TA 22 |      |

DESCRIBE POSSIBLE COLLATERAL DAMAGE.

WOOD STRUCTURE COLLAPSE AT 11 PSI  
STACKS OF LUMBER IN YARD AT 15 PSI

USE BACK OF THIS WORKSHEET FOR OTHER MEMORANDUMS.

500 MANHOURS INDIVIDUALLY 2 DAYS WITH 3 SHIFTS.  
500 MANHOURS CLOSE PACKED 1 DAY WITH 3 SHIFTS.

500 MANHOURS CLOSE PACKED 1 DAY WITH 3 SHIFTS.

### Relocation Demonstration #1

The small job shop that participated in this demonstration is representative not only of its type, but also of a small maintenance shop that might be part of a moderate sized manufacturing company. It is a one-man operation specializing in one-of-a-kind parts and minor electrical testing.

Total evacuation of the shop was determined to be the most efficient hardening technique for two principal reasons. First, being a small job shop accustomed to purchasing materials as needed, there were few materials available for in-place hardening. Second, the shop owned a light truck, which appeared capable of carrying a major portion, if not all, of the shop equipment.

The evacuation was carried out by two sons of the shop owner, under the owner's supervision. Shop equipment included several still cameras, and a movie camera with which the owner recorded his sons in action. The shop owner felt that the evacuation could be carried out either by two inexperienced people under supervision (as here), or by two people alone, provided that at least one had experience in efficient and safe loading of trucks.

The heavy shop equipment was loaded on the truck first. The equipment was moved with a hand-pushed forklift, a handtruck, and pipe rollers. The truck had a lift gate, which was used along with the forklift, to raise the equipment into the truck bed. After the heavy equipment was loaded, the storage cabinets were emptied of the fragile electronic equipment and loaded flat on the truck bed. The electronic equipment was then replaced in the cabinets to protect it during transport. Once the delicate equipment had been taken care of, remaining small handtools and other small non-fragile equipment were loaded into open 55-gallon barrels and the

barrels stacked on top of the cabinets. A small milling machine was also placed on top of the cabinets.

After loading, the shop equipment was secured with tarps and rope in a manner the shop owner felt would be sufficient for traveling several hundred miles without loss or damage. The entire loading procedure was accomplished in 5½ hours by two persons. If necessary, the forklift used for loading could have been replaced with a chain hoist and an A frame, but additional time would have been required.

Both SSI and the shop owner performed hardening analyses, using the manual prior to actual performance of the evacuation. The shop owner, in the course of the evacuation exercise, found that his estimate, and the estimate made by SSI personnel, of the amount of equipment that could be loaded on the truck fell significantly short of the actuality. In addition to the items listed on the equipment inventory sheets (see data sheets following this discussion), a mill, an acetylene torch (oxygen and acetylene bottles), a grinder, disc and belt sander, miscellaneous supplies, supply cabinets with nuts and bolts, and a 15-amp, 220-volt single phase gasoline-powered electrical generator were loaded on the truck.

Survival of a number of these small job shops could make an invaluable contribution in a post-disaster environment. The shop in this study, given fuel to run its generator, could start, almost immediately, to manufacture replacement parts for damaged equipment. Presuming that the shop owner was able to move his truck to an unimpacted area, he need merely unload his equipment into some shelter, obtain working stock and gasoline, and begin operation.

*(Text continues on p. 97)*

SMALL JOB SHOP

PAGE # 1 HARDENING DECISION WORKSHEET

EQUIPMENT INVENTORY WORKSHEET # 1  
PAGE # 1  
SCRAP MEMBERS

ALSO, AREA

| ITEM NO | EQUIPMENT NAME AND DESCRIPTION | QTY | SIZE      | REMARKS      | SHUT DOWN TIME | EST | NR | E+R | BLAST | SCHED | PRIORITY | LOADING | STORAGE | EVALUATE | HARDENING METHOD                 | MATERIALS REQUIRED | ESTIMATED COST | REMARKS |
|---------|--------------------------------|-----|-----------|--------------|----------------|-----|----|-----|-------|-------|----------|---------|---------|----------|----------------------------------|--------------------|----------------|---------|
| 1       | BAND SAW                       | 1   | 4' 4' 3'  | FREESTANDING | 0              |     |    |     |       |       |          |         |         |          | LOAD ON STAKE TRUCK AND EVALUATE | HAND TRUCK         | 2 MEN 1/2 HRS  | TH      |
| 2       | DRILL PRESS                    | 1   | 11' 6' 3' | FREESTANDING | 0              |     |    |     |       |       |          |         |         |          | LOAD ON STAKE TRUCK AND EVALUATE | HAND TRUCK         | 2 MEN 1/2 HRS  | TH      |
| 3       | BENCH LATHE                    | 1   | 11' 2' 1' | FREESTANDING | 0              |     |    |     |       |       |          |         |         |          | LOAD ON STAKE TRUCK AND EVALUATE | HAND TRUCK         | 2 MEN 1/2 HRS  | TH      |
| 4       | WELDER                         | 1   | 11' 2' 1' | FREESTANDING | 0              |     |    |     |       |       |          |         |         |          | LOAD ON STAKE TRUCK AND EVALUATE | HAND TRUCK         | 2 MEN 1/2 HRS  | TH      |
| 5       | PORTABLE COMPRESSOR            | 1   | 11' 2' 1' | FREESTANDING | 0              |     |    |     |       |       |          |         |         |          | LOAD ON STAKE TRUCK AND EVALUATE | HAND TRUCK         | 2 MEN 1/2 HRS  | TH      |
| 6       | STAKE TRUCK                    | 1   | 11' 2' 1' |              | 0              |     |    |     |       |       |          |         |         |          | LOAD AND EVALUATE                | GASOLINE           | 2 MEN 1 HRS    | TH      |
| 7       | PIPE DIES AND WHEELS           | 1   | 11' 2' 1' |              | 0              |     |    |     |       |       |          |         |         |          | LOAD ON STAKE TRUCK AND EVALUATE | HAND TRUCK         | 2 MEN 1/2 HRS  | TH      |

DESCRIBE POSSIBLE COLLATERAL DAMAGE

PRIORITY = A+B or A+C (lowest sum)

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION IF REQUIRED

SMALL JOB SHOP

PAGE # 2

HARDENING DECISION WORKSHEET

PAGE # 2

EQUIPMENT INVENTORY WORKSHEET

SQUAD MEMBERS

BLDG

| AREA | TH | IN | EQUIPMENT NAME AND DESCRIPTION                      | QTY | SIZE  | REMARKS     | START DATE | END DATE | RR | E+RR | BLAST | STRONG | PRIORITY | REPAIR | REPLACE | HARDENING METHOD                 | MATERIALS REQUIRED | DATE  |
|------|----|----|---|-----|-------|-------------|------------|----------|----|------|-------|--------|----------|--------|---------|----------------------------------|--------------------|-------|
| 1    |    |    | HAND TRAILS IN BOX                                  | 2   | 1' 2' |             | 0          |          |    |      |       |        |          |        |         | LOAD ON STAKE TRUCK AND EVALUATE | HAND TRUCK         | 2 MEN |
| 2    |    |    | REORDER 24" CHANNEL                                 | 2   | 1' 2' | PRESTANDING | 0          |          |    |      |       |        |          |        |         | LOAD ON STAKE TRUCK AND EVALUATE | HAND TRUCK         | 2 MEN |
| 3    |    |    | PHOTOGRAPHIC EQUIPMENT                              | 1   | 1' 2' | PRESTANDING | 0          |          |    |      |       |        |          |        |         | LOAD ON STAKE TRUCK AND EVALUATE | HAND TRUCK         | 2 MEN |
| 4    |    |    | CABINETS OF MISCELLANEOUS ELECTRICAL TEST EQUIPMENT | 3   | 1' 2' | PRESTANDING | 0          |          |    |      |       |        |          |        |         | LOAD ON STAKE TRUCK AND EVALUATE | HAND TRUCK         | 2 MEN |
| 5    |    |    |   |     |       |             |            |          |    |      |       |        |          |        |         |                                  |                    |       |
| 6    |    |    |   |     |       |             |            |          |    |      |       |        |          |        |         |                                  |                    |       |
| 7    |    |    |   |     |       |             |            |          |    |      |       |        |          |        |         |                                  |                    |       |

PRIORITY = A+B or A+C (lowest sum)

RATING

DESCRIBE POSSIBLE COLLATERAL DAMAGE

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION IF DESIRED

SMALL JOB SHOP

EQUIPMENT INVENTORY WORKSHEET # 1 PAGE 1

HARDENING DECISION WORKSHEET # 1 PAGE 1

AREA

| NO. | EQUIPMENT NAME AND DESCRIPTION | QTY | SIZE             | REMARKS      | PUT DOWN TIME | RR |
|-----|--------------------------------|-----|------------------|--------------|---------------|----|
| 1   | BAND SAW                       | 1   | 4' 4' 3'         | FREESTANDING | 0             | 3  |
| 2   | DRILL PRESS                    | 1   | 6' 3' 3'         | FREESTANDING | 0             | 2  |
| 3   | BENCH LATHE                    | 1   | 2' 5' 2'         | FREESTANDING | 0             | 3  |
| 4   | WELDER                         | 1   | 2 1/2' 1 1/2'    | FREESTANDING | 0             | 2  |
| 5   | PORTABLE COMPRESSOR            | 1   | 2' 3 1/2' 1 1/2' | FREESTANDING | 0             | 3  |
| 6   | STAKE TRUCK                    | 1   |                  |              | 0             | 2  |
| 7   | PIPE DIES AND WRENCHES         | 1   |                  |              | 0             | 3  |

DESCRIBE POSSIBLE COLLATERAL DAMAGE

THE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED.

# IN-PLANT ANALYSIS

| E+R | STANDARD | PRIORITY | LOADING AND UNLOADING | HARDENING METHOD                 | MATERIALS REQUIRED | NEW OR REWORKED |
|-----|----------|----------|-----------------------|----------------------------------|--------------------|-----------------|
|     |          |          |                       | LOAD ON STAKE TRUCK AND EVALUATE | TRUCK              | 2 MEN 5 HRS     |
|     |          |          |                       | LOAD ON STAKE TRUCK AND EVALUATE | TRUCK              | 2 MEN 5 HRS     |
|     |          |          |                       | LOAD ON STAKE TRUCK AND EVALUATE | TRUCK              | 2 MEN 5 HRS     |
|     |          |          |                       | LOAD ON STAKE TRUCK AND EVALUATE | TRUCK              | 2 MEN 5 HRS     |
|     |          |          |                       | LOAD ON STAKE TRUCK AND EVALUATE | TRUCK              | 2 MEN 5 HRS     |
|     |          |          |                       | LOAD ON STAKE TRUCK AND EVALUATE | TRUCK              | 2 MEN 5 HRS     |
|     |          |          |                       | LOAD AND EVALUATE                | GASOLINE           | 2 MEN 5 HRS     |
|     |          |          |                       | LOAD ON STAKE TRUCK AND EVALUATE | TRUCK              | 2 MEN 5 HRS     |

RATING

PRIORITY = A+B or A+C (lowest sum)

# IN-PLANT ANALYSIS

SMALL JOB SHOP

EQUIPMENT INVENTORY WORKSHEET # 2

PAGE 2

AREA

DATE

SQUAD MEMBERS

HARDENING DECISION WORKSHEET

| ITEM NO. | EQUIPMENT NAME AND DESCRIPTION                      | QTY | SIZE         | REMARKS | SHOT DOWN TIME | PR | BLAST | STRUCTURE | PRIORITY | LOADING | EVALUATE | HARDENING METHOD                 | MATERIALS REQUIRED | MANPOWER    | ESTIMATED COST | NEW |
|----------|---|-----|--------------|---------|----------------|----|-------|-----------|----------|---------|----------|----------------------------------|--------------------|-------------|----------------|-----|
| 1        | HAND TOOLS IN BOX                                   | 1   | 1'           |         | 0              | 2  |       |           |          |         |          | LOAD ON STAKE TRUCK AND EVALUATE | TRUCK              | 2 MEN 5 HRS |                |     |
| 2        | RECORDER 24-CHANNEL                                 | 2   | 2 1/2'       |         | 0              | 3  |       |           |          |         |          | LOAD ON STAKE TRUCK AND EVALUATE | TRUCK              | 2 MEN 5 HRS |                |     |
| 3        | PHOTOGRAPHIC EQUIPMENT                              | 1   | 1 1/2'       |         | 0              | 3  |       |           |          |         |          | LOAD ON STAKE TRUCK AND EVALUATE | TRUCK              | 2 MEN 5 HRS |                |     |
| 4        | CABINETS OF MISCELLANEOUS ELECTRONIC TEST EQUIPMENT | 3   | 6' 5' 1 1/2' |         | 0              | 3  |       |           |          |         |          | LOAD ON STAKE TRUCK AND EVALUATE | TRUCK              | 2 MEN 5 HRS |                |     |
| 5        |   |     |              |         |                |    |       |           |          |         |          |                                  |                    |             |                |     |
| 6        |   |     |              |         |                |    |       |           |          |         |          |                                  |                    |             |                |     |
| 7        |   |     |              |         |                |    |       |           |          |         |          |                                  |                    |             |                |     |

PRIORITY = A+B or A+C (lowest sum)

DESCRIBE POSSIBLE COLLATERAL DAMAGE

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION IF DESIRED

## Relocation Demonstration #2

This manufacturer of large electric switches, etc., is a facility with 15 to 20 employees. The company was involved in planning a move to a new location. Because it was very important to minimize lost production time, this expeditious move provided data on manpower, time, and resources required to evacuate the old site. This information is directly pertinent to a preplanned hardening exercise.

Four men completed the entire move in five working days, which included setting up the new facility. It was estimated that less than eight man-days of this was used to evacuate the old site. Consequently, the entire plant would be moved out in one day, using half the plant personnel and a single forty-foot flatbed truck. Such a vehicle was not available as part of company equipment, but the plant was located next door to two trucking firms with nothing to harden or move other than rolling stock. It is anticipated that a joint effort could be worked out in an emergency.

*(Text continues on p. 101)*



# SSI ANALYSIS

# 1 HARPENING DECISION WORKSHEET

EQUIPMENT INVENTORY WORKSHEET # 1

SEALING MEMBERS

AREA SHOP

| TO | EQUIPMENT NAME AND DESCRIPTION | QTY | SIZE                | REMARKS       | NOT DOWN TIME | EL | NR | PLAST | STRUCTURE | PRIORITY | LOCATION | MOVING | FIXING | HARPENING METHOD | MATERIALS REQUIRED | NEW EQUIPMENT | HOST AREA |
|----|--------------------------------|-----|---------------------|---------------|---------------|----|----|-------|-----------|----------|----------|--------|--------|------------------|--------------------|---------------|-----------|
| 1  | DRILL PRESS                    | 6   | 12" 14" 16" 18" 20" | FREE STANDING | 0             |    |    | 2     |           |          |          |        |        | EVALUATE         | DOLLY/ TRUCK       |               | HOST AREA |
| 2  | ROTARY PUNCH                   | 1   | 12" 14" 16" 18" 20" | FREE STANDING | 0             |    |    | 2     |           |          |          |        |        | EVALUATE         | DOLLY/ TRUCK       |               | HOST AREA |
| 3  | BAND SAW                       | 1   | 12" 14" 16" 18" 20" | FREE STANDING | 0             |    |    | 2     |           |          |          |        |        | EVALUATE         | DOLLY/ TRUCK       |               | HOST AREA |
| 4  | BENCH DRILL PRESS              | 3   | 12" 14" 16" 18" 20" | FREE STANDING | 0             |    |    | 2     |           |          |          |        |        | EVALUATE         | DOLLY/ TRUCK       |               | HOST AREA |
| 5  | LATHE                          | 1   | 12" 14" 16" 18" 20" | FREE STANDING | 0             |    |    | 2     |           |          |          |        |        | EVALUATE         | DOLLY/ TRUCK       |               | HOST AREA |
| 6  | CABINETS WITH HARDWARE         | 20  | 12" 14" 16" 18" 20" | FREE STANDING | 0             |    |    | 2     |           |          |          |        |        | EVALUATE         | DOLLY/ TRUCK       |               | HOST AREA |
| 7  | ANGLE IRON SHEAR               | 1   | 12" 14" 16" 18" 20" | FREE STANDING | 0             |    |    | 2     |           |          |          |        |        | EVALUATE         | DOLLY/ TRUCK       |               | HOST AREA |

RATING

DESCRIBE POSSIBLE COLLATERAL DAMAGE  
NONE - MOVE ENTIRE PLANT EQUIPMENT TO HOST AREA - 1ST OF 3 PAGES

USE BACK OF THIS WORKSHEET FOR SKETCHES  
SHOWING EQUIPMENT LOCATION, IF DESIRED

### Move-And-Harden Demonstration

This demonstration was conducted in a precast concrete plant in San Jose, California. This was a particularly interesting exercise in that the owner of the plant preferred to conduct the entire operation without technical input from the project team. After reading the manual and going through all the forms, the owner decided the Management Planning Guide; i.e., Booklet # 1, (see Figure 1) provided all the information he needed to develop his own unique hardening and recovery strategy. This strategy was based on a cooperative effort with several other small business entrepreneurs in the area, combining to form an entirely new business operation in the post-attack environment. The hardening strategy included a list of equipment essential to this post-attack business, a hardening procedure, and a novel concept for a hardened shelter onsite, which will be discussed subsequently.

The post-attack business was quite interesting. In its present form the firm produces and erects precast building components such as columns, beams, and wall panels. The owner's analysis indicated that the best immediate post-attack business for his company would not be precast concrete, but salvage, and to this end he would implement a form of mutual aid pact with other local businessmen in the area who were well known to him. These included a trucking firm, a construction firm with both earth-moving and agricultural equipment, and a welding and repair company. This decision aided in the identification of the essential equipment for each of the organizations, which included trucks, forklifts, cranes, tractors, generators, welders, etc.

His hardening strategy was to move equipment to a better location nearby -- in this case, a wide ditch (see Figure 37) on the perimeter of the precast concrete plant. An overall view of the plant can be seen in

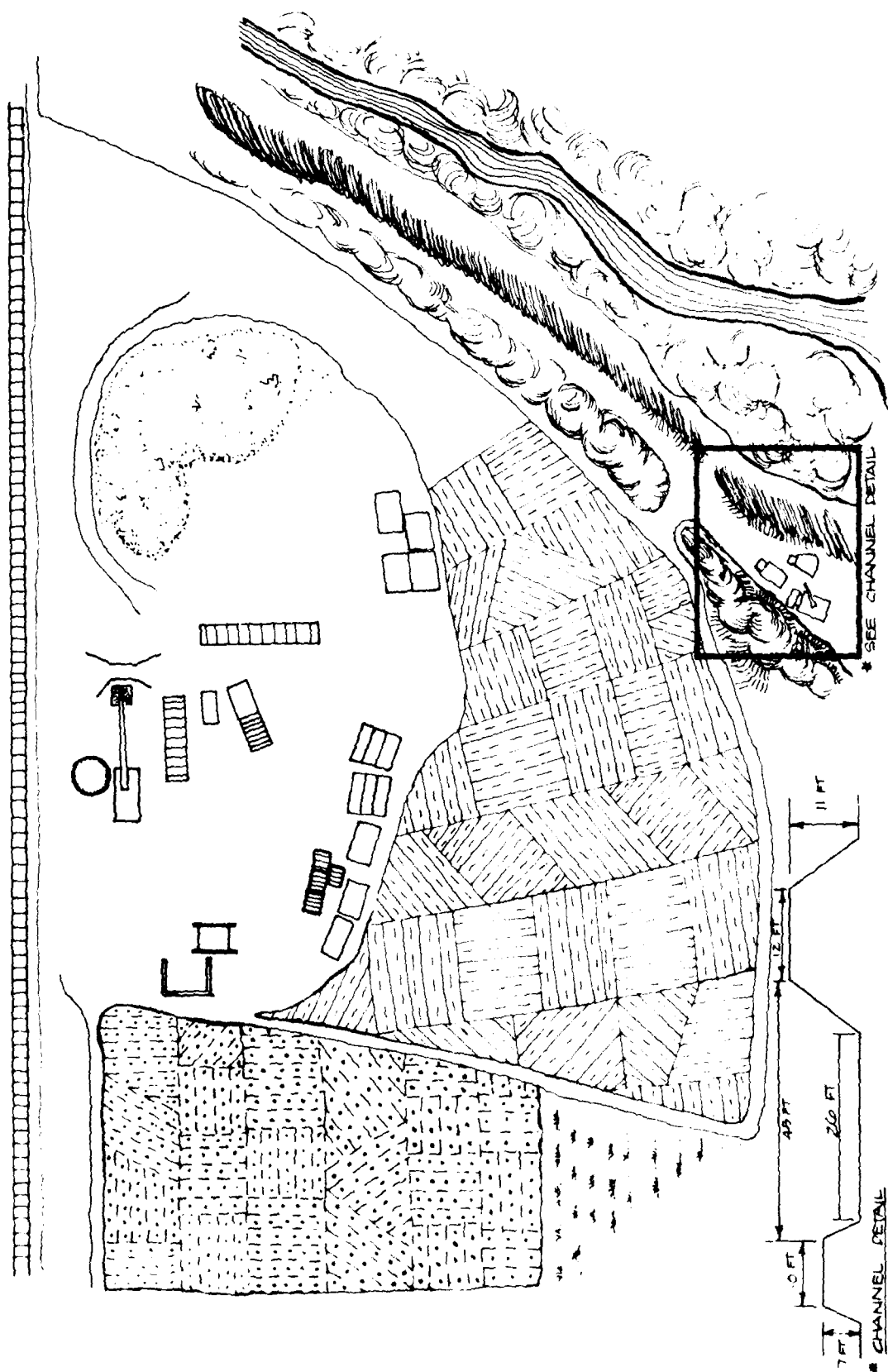


Fig. 37. A Composite View of Plant and Nearby Hardening Site.

Figures 38 and 39. With the aid of a crawler tractor and an endloader from the construction firm, the ditch was cleared of brush (to eliminate fire danger) and leveled (see Figures 40-42). In the event of escalating world tensions, the ditch would be prepared and used as a parking area for all equipment not in use. The rationale was that pressure, *per se*, would not cause much damage to heavy equipment; rather, drag forces, overturning, and missile impact would be the main concern, and the ditch would afford protection. With this strategy, the owner felt that, once prepared, he could assemble his entire complement of post-attack business equipment in the ditch, nights or within one hour after an attack warning.

Another benefit of the strategy selected is that it would provide maximum flexibility for continued operation, whatever the final circumstance that develops. Various views of the equipment installed in this ditch can be seen in Figures 43 through 47. With sufficient warning time, some of the agricultural equipment could also be moved into the ditch, to be used post-attack to cultivate the adjacent fields. This equipment would also be stored in the ditch at night, during periods of high international tension, and be readily available each day.

Another interesting facet of this industry-conducted demonstration was the construction of a key worker shelter on the property. This was accomplished by the acquisition of a prefabricated underground vault (typical of those used by telephone and electric utilities), shown in Figures 48 and 49. A hole was dug by a crawler tractor, the vault assembled including a pipe entrance, and the shelter covered with dirt. This sequence is shown in Figures 50 through 60. It is estimated that, with provision of a blast closure and a ventilation system, this would be an adequate shelter and could probably survive 40 to 80 psi. The construction of the shelter, from the time that the equipment was called in to the time personnel entered the shelter, took less than 10 hours and involved only three men.

As a point of interest, the availability of such shelters was assessed

via a survey conducted in the San Francisco Bay Area. The survey indicated that there are upwards of 100,000 vaults in various manufacturers' stocks or already installed. Vaults of this type, plus manholes and various sewer systems, could make a valuable contribution to key worker protection.

The post-attack business was assessed by the proprietor to withstand 15 psi when hardened. Hardening the entire pre-attack business would, in SSI's assessment, enable it to withstand only 5 psi, if the conveyor and hopper (see Figure 38) were guyed, or 7 psi if these two items were laid on the ground and the hopper filled with material.

*(Text continues on p. 125)*



Fig. 38. View of Precast Concrete Yard Area from Hardening Site.



Fig. 39. Equipment in Precast Concrete Yard.



Fig. 40. Closeup View of Drainage Channel.

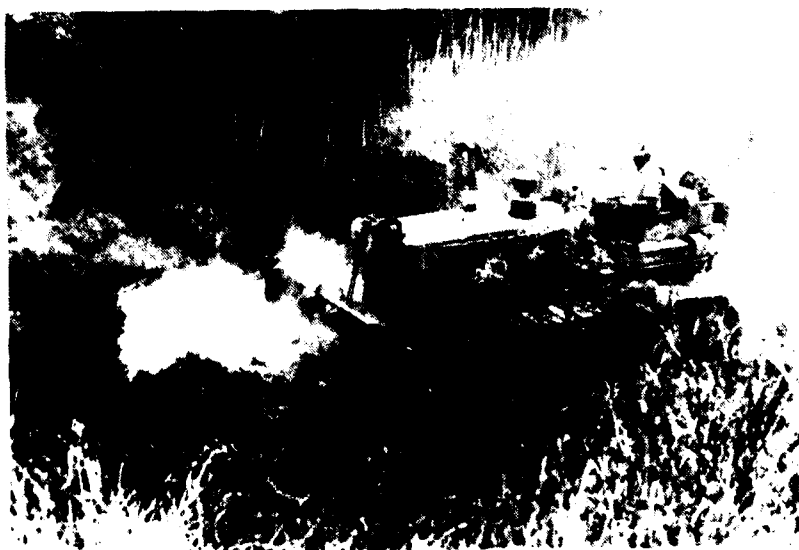


Fig. 41. Cat Clearing Fire Hazard.



Fig. 42. Cleared Channel.

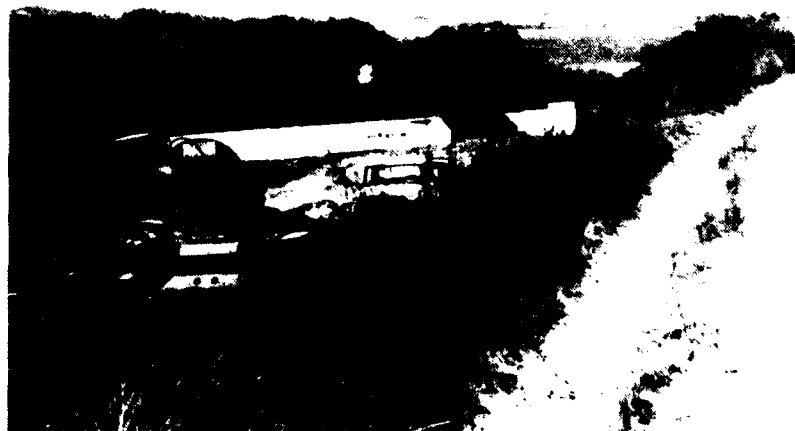


Fig. 43 Mobile Crane, Forklift, Tractor, Pickup in Cleared Channel.





Fig. 44. Tractor and Pickup in Cleared Channel Showing Berm.



Fig. 45. View of Channel, Berm, Forklift, Mobile Crane, Tractor, Pickup, and Welder.

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INDUSTRIAL HARDENING DEMONSTRATION.(U)  
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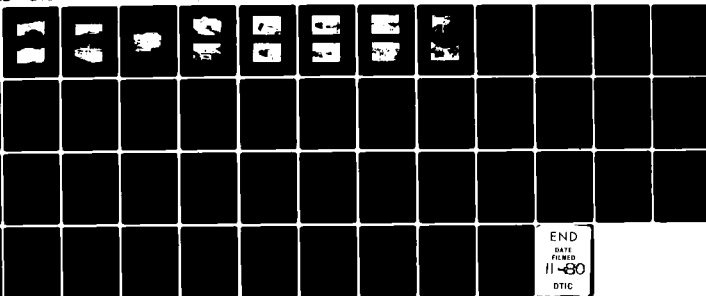
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Fig. 46. View Up Channel With All of Figure 45 Equipment, Flatbed Truck and Crane.

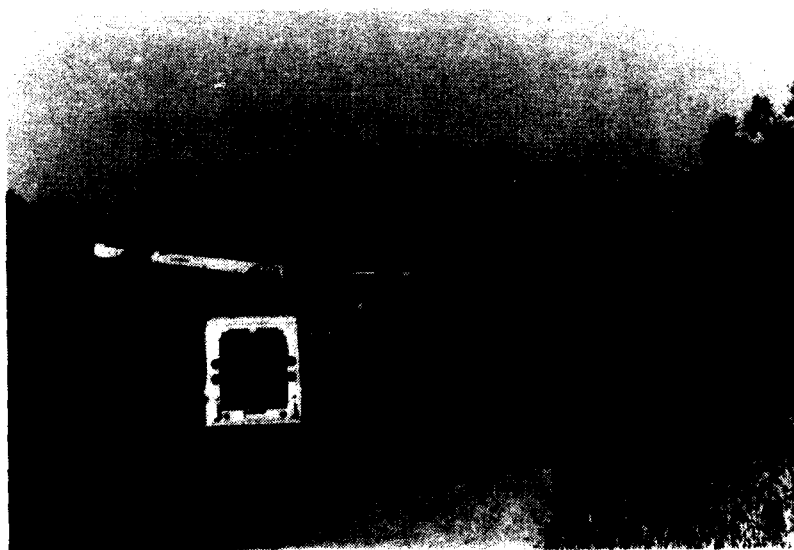


Fig. 47. Final View Up Channel With Semi-Tractor and Van With Generator and Fuel Supply Inside.



Fig. 48. Vault Inventory at Fabrication Plant.

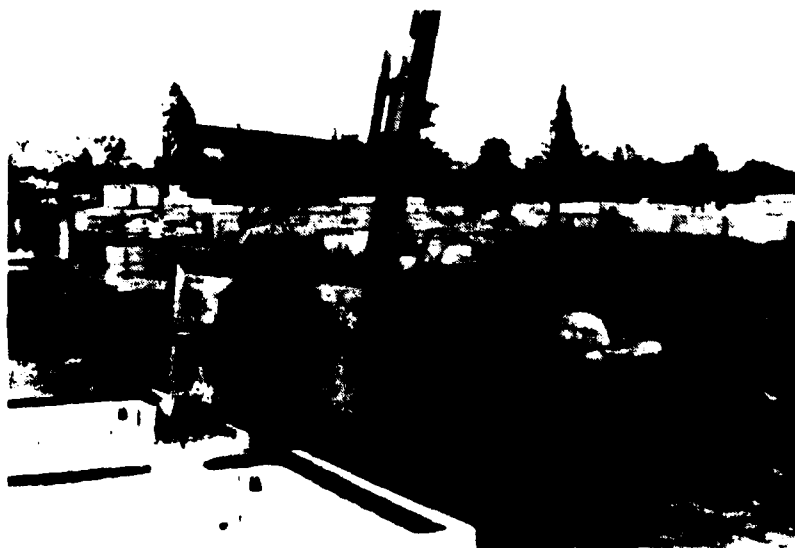


Fig. 49. Vault Center Section.



Fig. 50. Cat Digging Hole in Channel for Vault.

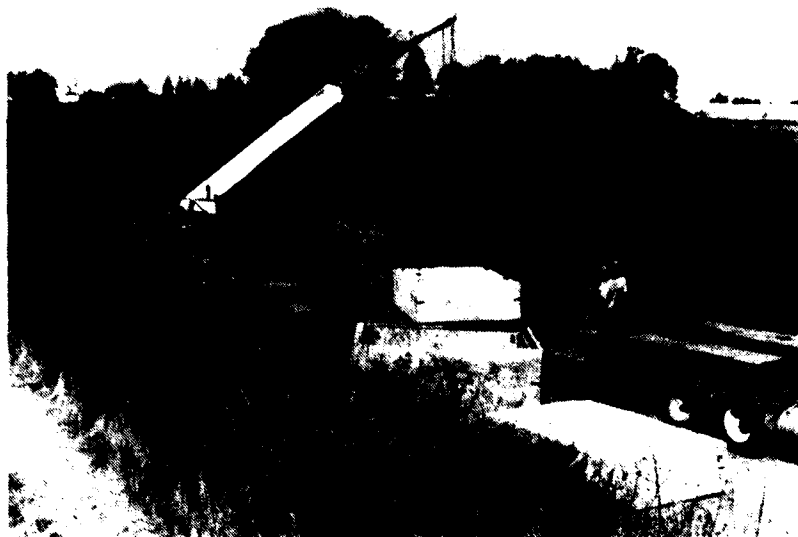


Fig. 51. Vault Offloaded From Flatbed at Channel Site.

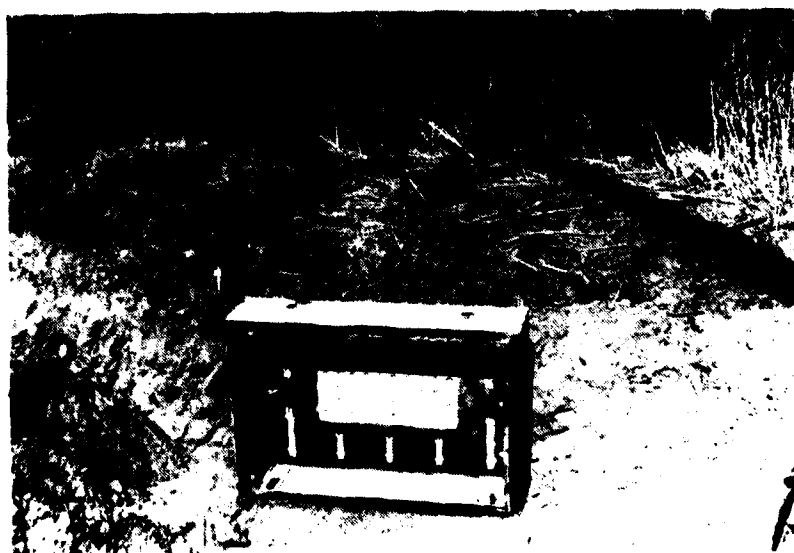


Fig. 52. Vault End Being Placed in Hole.

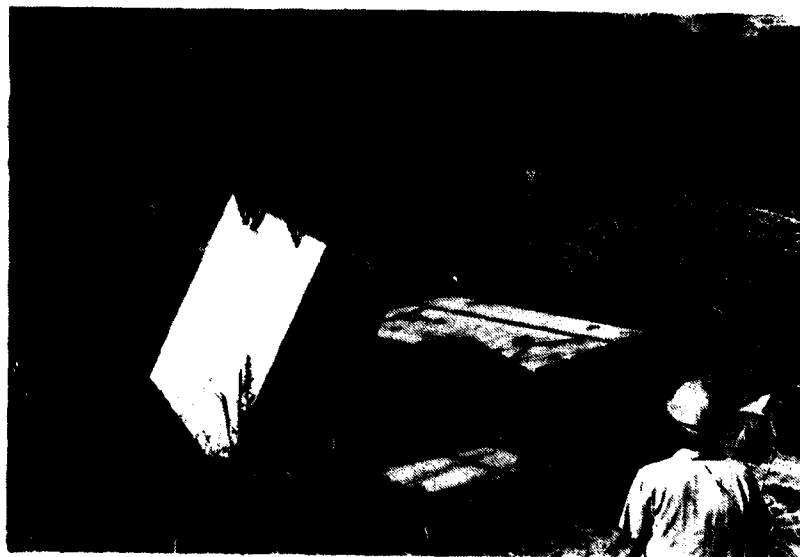


Fig. 53. Opposite End of Vault Being Placed.

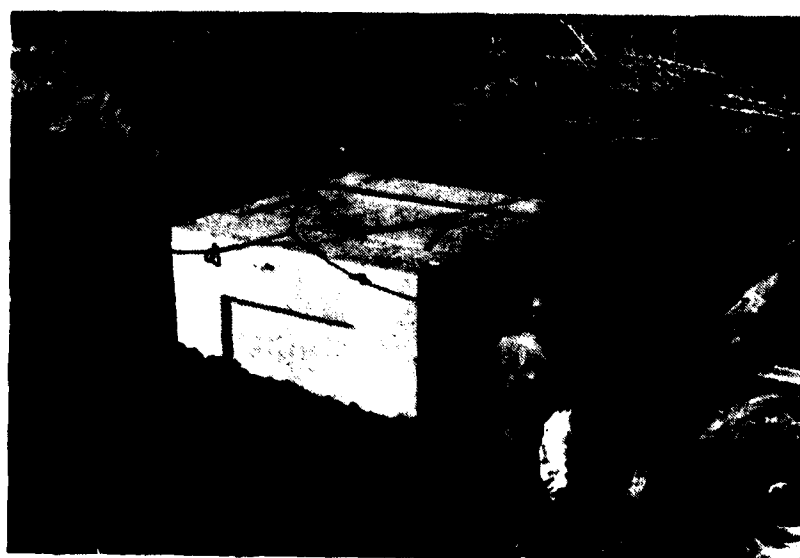


Fig. 54. Completed Vault in Hole.

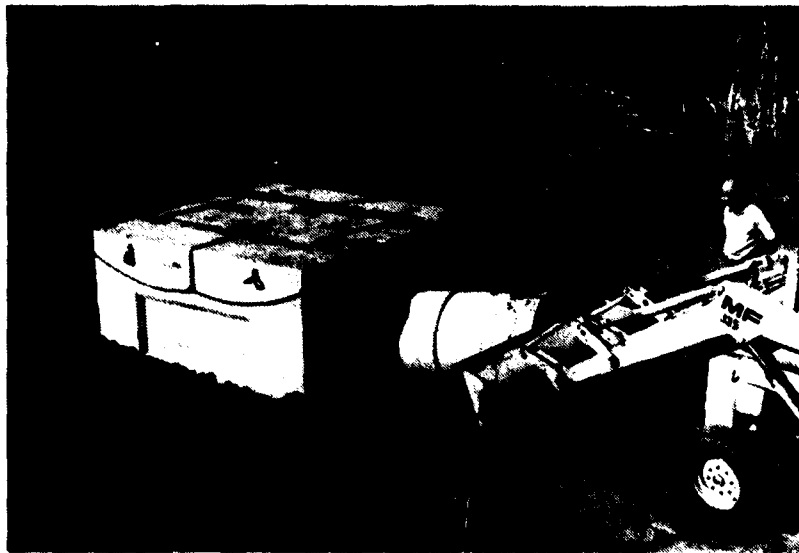


Fig. 55. Vault Entrance Being Placed.

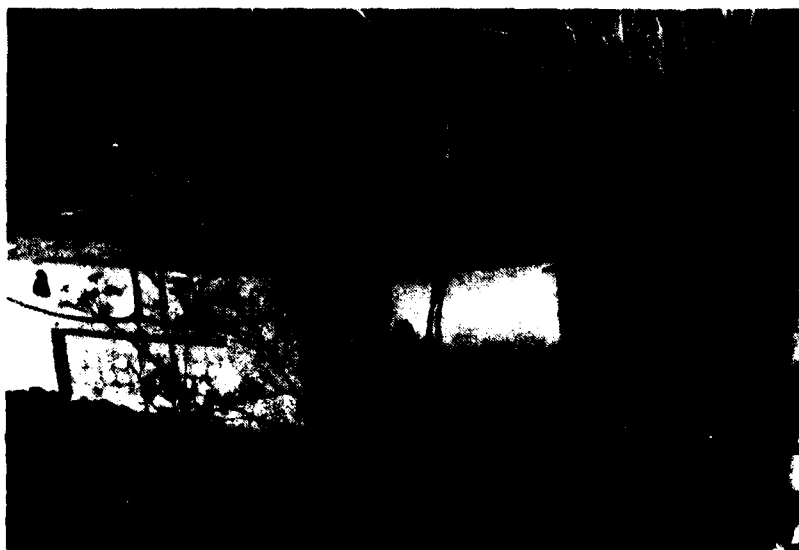


Fig. 56. Commencing Backfilling of Vault.





Fig. 57. Backfilling Vault.



Fig. 58. Final Covering of Vault.



Fig. 59. Entering the Completed Key Worker Shelter.



Fig. 60. Inside the Key Worker Shelter.



| DATE     | DESCRIPTION | AMOUNT | CHECK NO. | DEPOSITED | BALANCE | REMARKS |
|----------|-------------|--------|-----------|-----------|---------|---------|
| 10/1/78  | DEPOSIT     | 100.00 |           |           | 100.00  |         |
| 10/2/78  | PAYROLL     | 50.00  | 101       |           | 50.00   |         |
| 10/3/78  | RENT        | 25.00  | 102       |           | 25.00   |         |
| 10/4/78  | UTILITIES   | 15.00  | 103       |           | 10.00   |         |
| 10/5/78  | SALES       | 75.00  | 104       |           | 35.00   |         |
| 10/6/78  | EXPENSES    | 30.00  | 105       |           | 5.00    |         |
| 10/7/78  | DEPOSIT     | 120.00 |           |           | 125.00  |         |
| 10/8/78  | PAYROLL     | 55.00  | 106       |           | 70.00   |         |
| 10/9/78  | RENT        | 25.00  | 107       |           | 45.00   |         |
| 10/10/78 | UTILITIES   | 15.00  | 108       |           | 30.00   |         |
| 10/11/78 | SALES       | 80.00  | 109       |           | 110.00  |         |
| 10/12/78 | EXPENSES    | 35.00  | 110       |           | 75.00   |         |
| 10/13/78 | DEPOSIT     | 130.00 |           |           | 205.00  |         |
| 10/14/78 | PAYROLL     | 60.00  | 111       |           | 145.00  |         |
| 10/15/78 | RENT        | 25.00  | 112       |           | 120.00  |         |
| 10/16/78 | UTILITIES   | 15.00  | 113       |           | 105.00  |         |
| 10/17/78 | SALES       | 85.00  | 114       |           | 190.00  |         |
| 10/18/78 | EXPENSES    | 40.00  | 115       |           | 150.00  |         |
| 10/19/78 | DEPOSIT     | 140.00 |           |           | 290.00  |         |
| 10/20/78 | PAYROLL     | 65.00  | 116       |           | 225.00  |         |
| 10/21/78 | RENT        | 25.00  | 117       |           | 200.00  |         |
| 10/22/78 | UTILITIES   | 15.00  | 118       |           | 185.00  |         |
| 10/23/78 | SALES       | 90.00  | 119       |           | 275.00  |         |
| 10/24/78 | EXPENSES    | 45.00  | 120       |           | 230.00  |         |
| 10/25/78 | DEPOSIT     | 150.00 |           |           | 380.00  |         |
| 10/26/78 | PAYROLL     | 70.00  | 121       |           | 310.00  |         |
| 10/27/78 | RENT        | 25.00  | 122       |           | 285.00  |         |
| 10/28/78 | UTILITIES   | 15.00  | 123       |           | 270.00  |         |
| 10/29/78 | SALES       | 95.00  | 124       |           | 365.00  |         |
| 10/30/78 | EXPENSES    | 50.00  | 125       |           | 315.00  |         |
| 10/31/78 | DEPOSIT     | 160.00 |           |           | 475.00  |         |
| 11/1/78  | PAYROLL     | 75.00  | 126       |           | 400.00  |         |
| 11/2/78  | RENT        | 25.00  | 127       |           | 375.00  |         |
| 11/3/78  | UTILITIES   | 15.00  | 128       |           | 360.00  |         |
| 11/4/78  | SALES       | 100.00 | 129       |           | 460.00  |         |
| 11/5/78  | EXPENSES    | 55.00  | 130       |           | 405.00  |         |
| 11/6/78  | DEPOSIT     | 170.00 |           |           | 575.00  |         |
| 11/7/78  | PAYROLL     | 80.00  | 131       |           | 495.00  |         |
| 11/8/78  | RENT        | 25.00  | 132       |           | 470.00  |         |
| 11/9/78  | UTILITIES   | 15.00  | 133       |           | 455.00  |         |
| 11/10/78 | SALES       | 105.00 | 134       |           | 560.00  |         |
| 11/11/78 | EXPENSES    | 60.00  | 135       |           | 500.00  |         |
| 11/12/78 | DEPOSIT     | 180.00 |           |           | 680.00  |         |
| 11/13/78 | PAYROLL     | 85.00  | 136       |           | 595.00  |         |
| 11/14/78 | RENT        | 25.00  | 137       |           | 570.00  |         |
| 11/15/78 | UTILITIES   | 15.00  | 138       |           | 555.00  |         |
| 11/16/78 | SALES       | 110.00 | 139       |           | 665.00  |         |
| 11/17/78 | EXPENSES    | 65.00  | 140       |           | 600.00  |         |
| 11/18/78 | DEPOSIT     | 190.00 |           |           | 790.00  |         |
| 11/19/78 | PAYROLL     | 90.00  | 141       |           | 700.00  |         |
| 11/20/78 | RENT        | 25.00  | 142       |           | 675.00  |         |
| 11/21/78 | UTILITIES   | 15.00  | 143       |           | 660.00  |         |
| 11/22/78 | SALES       | 115.00 | 144       |           | 775.00  |         |
| 11/23/78 | EXPENSES    | 70.00  | 145       |           | 705.00  |         |
| 11/24/78 | DEPOSIT     | 200.00 |           |           | 905.00  |         |
| 11/25/78 | PAYROLL     | 95.00  | 146       |           | 810.00  |         |
| 11/26/78 | RENT        | 25.00  | 147       |           | 785.00  |         |
| 11/27/78 | UTILITIES   | 15.00  | 148       |           | 770.00  |         |
| 11/28/78 | SALES       | 120.00 | 149       |           | 890.00  |         |
| 11/29/78 | EXPENSES    | 75.00  | 150       |           | 815.00  |         |
| 11/30/78 | DEPOSIT     | 210.00 |           |           | 1025.00 |         |
| 11/31/78 | PAYROLL     | 100.00 | 151       |           | 925.00  |         |
| 12/1/78  | RENT        | 25.00  | 152       |           | 900.00  |         |
| 12/2/78  | UTILITIES   | 15.00  | 153       |           | 885.00  |         |
| 12/3/78  | SALES       | 125.00 | 154       |           | 1010.00 |         |
| 12/4/78  | EXPENSES    | 80.00  | 155       |           | 930.00  |         |
| 12/5/78  | DEPOSIT     | 220.00 |           |           | 1150.00 |         |
| 12/6/78  | PAYROLL     | 105.00 | 156       |           | 1045.00 |         |
| 12/7/78  | RENT        | 25.00  | 157       |           | 1020.00 |         |
| 12/8/78  | UTILITIES   | 15.00  | 158       |           | 1005.00 |         |
| 12/9/78  | SALES       | 130.00 | 159       |           | 1135.00 |         |
| 12/10/78 | EXPENSES    | 85.00  | 160       |           | 1050.00 |         |
| 12/11/78 | DEPOSIT     | 230.00 |           |           | 1280.00 |         |
| 12/12/78 | PAYROLL     | 110.00 | 161       |           | 1170.00 |         |
| 12/13/78 | RENT        | 25.00  | 162       |           | 1145.00 |         |
| 12/14/78 | UTILITIES   | 15.00  | 163       |           | 1130.00 |         |
| 12/15/78 | SALES       | 135.00 | 164       |           | 1265.00 |         |
| 12/16/78 | EXPENSES    | 90.00  | 165       |           | 1175.00 |         |
| 12/17/78 | DEPOSIT     | 240.00 |           |           | 1415.00 |         |
| 12/18/78 | PAYROLL     | 115.00 | 166       |           | 1300.00 |         |
| 12/19/78 | RENT        | 25.00  | 167       |           | 1275.00 |         |
| 12/20/78 | UTILITIES   | 15.00  | 168       |           | 1260.00 |         |
| 12/21/78 | SALES       | 140.00 | 169       |           | 1400.00 |         |
| 12/22/78 | EXPENSES    | 95.00  | 170       |           | 1305.00 |         |
| 12/23/78 | DEPOSIT     | 250.00 |           |           | 1555.00 |         |
| 12/24/78 | PAYROLL     | 120.00 | 171       |           | 1435.00 |         |
| 12/25/78 | RENT        | 25.00  | 172       |           | 1410.00 |         |
| 12/26/78 | UTILITIES   | 15.00  | 173       |           | 1395.00 |         |
| 12/27/78 | SALES       | 145.00 | 174       |           | 1540.00 |         |
| 12/28/78 | EXPENSES    | 100.00 | 175       |           | 1440.00 |         |
| 12/29/78 | DEPOSIT     | 260.00 |           |           | 1700.00 |         |
| 12/30/78 | PAYROLL     | 125.00 | 176       |           | 1575.00 |         |
| 12/31/78 | RENT        | 25.00  | 177       |           | 1550.00 |         |
| 1/1/79   | UTILITIES   | 15.00  | 178       |           | 1535.00 |         |
| 1/2/79   | SALES       | 150.00 | 179       |           | 1685.00 |         |
| 1/3/79   | EXPENSES    | 105.00 | 180       |           | 1580.00 |         |
| 1/4/79   | DEPOSIT     | 270.00 |           |           | 1850.00 |         |
| 1/5/79   | PAYROLL     | 130.00 | 181       |           | 1720.00 |         |
| 1/6/79   | RENT        | 25.00  | 182       |           | 1695.00 |         |
| 1/7/79   | UTILITIES   | 15.00  | 183       |           | 1680.00 |         |
| 1/8/79   | SALES       | 155.00 | 184       |           | 1835.00 |         |
| 1/9/79   | EXPENSES    | 110.00 | 185       |           | 1725.00 |         |
| 1/10/79  | DEPOSIT     | 280.00 |           |           | 2005.00 |         |
| 1/11/79  | PAYROLL     | 135.00 | 186       |           | 1870.00 |         |
| 1/12/79  | RENT        | 25.00  | 187       |           | 1845.00 |         |
| 1/13/79  | UTILITIES   | 15.00  | 188       |           | 1830.00 |         |
| 1/14/79  | SALES       | 160.00 | 189       |           | 1990.00 |         |
| 1/15/79  | EXPENSES    | 115.00 | 190       |           | 1875.00 |         |
| 1/16/79  | DEPOSIT     | 290.00 |           |           | 2165.00 |         |
| 1/17/79  | PAYROLL     | 140.00 | 191       |           | 2025.00 |         |
| 1/18/79  | RENT        | 25.00  | 192       |           | 2000.00 |         |
| 1/19/79  | UTILITIES   | 15.00  | 193       |           | 1985.00 |         |
| 1/20/79  | SALES       | 165.00 | 194       |           | 2150.00 |         |
| 1/21/79  | EXPENSES    | 120.00 | 195       |           | 2030.00 |         |
| 1/22/79  | DEPOSIT     | 300.00 |           |           | 2330.00 |         |
| 1/23/79  | PAYROLL     | 145.00 | 196       |           | 2185.00 |         |
| 1/24/79  | RENT        | 25.00  | 197       |           | 2160.00 |         |
| 1/25/79  | UTILITIES   | 15.00  | 198       |           | 2145.00 |         |
| 1/26/79  | SALES       | 170.00 | 199       |           | 2315.00 |         |
| 1/27/79  | EXPENSES    | 125.00 | 200       |           | 2190.00 |         |
| 1/28/79  | DEPOSIT     | 310.00 |           |           | 2500.00 |         |
| 1/29/79  | PAYROLL     | 150.00 | 201       |           | 2350.00 |         |
| 1/30/79  | RENT        | 25.00  | 202       |           | 2325.00 |         |
| 1/31/79  | UTILITIES   | 15.00  | 203       |           | 2310.00 |         |
| 2/1/79   | SALES       | 175.00 | 204       |           | 2485.00 |         |
| 2/2/79   | EXPENSES    | 130.00 | 205       |           | 2355.00 |         |
| 2/3/79   | DEPOSIT     | 320.00 |           |           | 2675.00 |         |
| 2/4/79   | PAYROLL     | 155.00 | 206       |           | 2520.00 |         |
| 2/5/79   | RENT        | 25.00  | 207       |           | 2495.00 |         |
| 2/6/79   | UTILITIES   | 15.00  | 208       |           | 2480.00 |         |
| 2/7/79   | SALES       | 180.00 | 209       |           | 2660.00 |         |
| 2/8/79   | EXPENSES    | 135.00 | 210       |           | 2525.00 |         |
| 2/9/79   | DEPOSIT     | 330.00 |           |           | 2855.00 |         |
| 2/10/79  | PAYROLL     | 160.00 | 211       |           | 2695.00 |         |
| 2/11/79  | RENT        | 25.00  | 212       |           | 2670.00 |         |
| 2/12/79  | UTILITIES   | 15.00  | 213       |           | 2655.00 |         |
| 2/13/79  | SALES       | 185.00 | 214       |           | 2840.00 |         |
| 2/14/79  | EXPENSES    | 140.00 | 215       |           | 2700.00 |         |
| 2/15/79  | DEPOSIT     | 340.00 |           |           | 3040.00 |         |
| 2/16/79  | PAYROLL     | 165.00 | 216       |           | 2875.00 |         |
| 2/17/79  | RENT        | 25.00  | 217       |           | 2850.00 |         |
| 2/18/79  | UTILITIES   | 15.00  | 218       |           | 2835.00 |         |
| 2/19/79  | SALES       | 190.00 | 219       |           | 3025.00 |         |
| 2/20/79  | EXPENSES    | 145.00 | 220       |           | 2880.00 |         |
| 2/21/79  | DEPOSIT     | 350.00 |           |           | 3230.00 |         |
| 2/22/79  | PAYROLL     | 170.00 | 221       |           | 3060.00 |         |
| 2/23/79  | RENT        | 25.00  | 222       |           | 3035.00 |         |
| 2/24/79  | UTILITIES   | 15.00  | 223       |           | 3020.00 |         |
| 2/25/79  | SALES       | 195.00 | 224       |           | 3215.00 |         |
| 2/26/79  | EXPENSES    | 150.00 | 225       |           | 3065.00 |         |
| 2/27/79  | DEPOSIT     | 360.00 |           |           | 3425.00 |         |
| 2/28/79  | PAYROLL     | 175.00 | 226       |           | 3250.00 |         |
| 2/29/79  | RENT        | 25.00  | 227       |           | 3225.00 |         |
| 2/30/79  | UTILITIES   | 15.00  | 228       |           | 3210.00 |         |
| 3/1/79   | SALES       | 200.00 | 229       |           | 3410.00 |         |
| 3/2/79   | EXPENSES    | 155.00 | 230       |           | 3255.00 |         |
| 3/3/79   | DEPOSIT     | 370.00 |           |           | 3625.00 |         |
| 3/4/79   | PAYROLL     | 180.00 | 231       |           | 3445.00 |         |
| 3/5/79   | RENT        | 25.00  | 232       |           | 3420.00 |         |
| 3/6/79   | UTILITIES   | 15.00  | 233       |           | 3405.00 |         |
| 3/7/79   | SALES       | 205.00 | 234       |           | 3600.00 |         |
| 3/8/79   | EXPENSES    | 160.00 | 235       |           | 3440.00 |         |
| 3/9/79   | DEPOSIT     | 380.00 |           |           | 3820.00 |         |
| 3/10/79  | PAYROLL     | 185.00 | 236       |           | 3635.00 |         |
| 3/11/79  | RENT        | 25.00  | 237       |           | 3610.00 |         |
| 3/12/79  | UTILITIES   | 15.00  | 238       |           | 3595.00 |         |
| 3/13/79  | SALES       | 210.00 | 239       |           | 3805.00 |         |
| 3/14/79  | EXPENSES    | 165.00 | 240       |           | 3640.00 |         |
| 3/15/79  | DEPOSIT     | 390.00 |           |           | 4030.00 |         |
| 3/16/79  | PAYROLL     | 190.00 | 241       |           | 3840.00 |         |
| 3/17/79  | RENT        | 25.00  | 242       |           | 3815.00 |         |
| 3/18/79  | UTILITIES   | 15.00  | 243       |           | 3800.00 |         |
| 3/19/79  | SALES       | 215.00 | 244       |           | 4015.00 |         |
| 3/20/79  | EXPENSES    | 170.00 | 245       |           | 3845.00 |         |
| 3/21/79  | DEPOSIT     | 400.00 |           |           | 4245.00 |         |
| 3/22/79  | PAYROLL     | 195.00 | 246       |           | 4050.00 |         |
| 3/23/79  | RENT        | 25.00  | 247       |           | 4025.00 |         |
| 3/24/79  | UTILITIES   | 15.00  | 248       |           | 4010.00 |         |
| 3/25/79  | SALES       | 220.00 | 249       |           | 4230.00 |         |
| 3/26/79  | EXPENSES    | 175.00 | 250       |           | 4055.00 |         |
| 3/27/79  | DEPOSIT     | 410.00 |           |           | 4465.00 |         |
| 3/28/79  | PAYROLL     | 200.00 | 251       |           | 4265.00 |         |
| 3/29/79  | RENT        | 25.00  | 252       |           | 4240.00 |         |
| 3/30/79  | UTILITIES   | 15.00  | 253       |           | 4225.00 |         |
| 3/31/79  | SALES       | 225.00 | 254       |           | 4450.00 |         |
| 4/1/79   | EXPENSES    | 180.00 | 255       |           | 4270.00 |         |
| 4/2/79   | DEPOSIT     | 420.00 |           |           | 4690.00 |         |
| 4/3/79   | PAYROLL     | 205.00 | 256       |           | 4485.00 |         |
| 4/4/79   | RENT        | 25.00  | 257       |           | 4460.00 |         |
| 4/5/79   | UTILITIES   | 15.00  | 258       |           | 4445.00 |         |
| 4/6/79   | SALES       | 230.00 | 259       |           | 4675.00 |         |
| 4/7/79   | EXPENSES    | 185.00 | 260       |           | 4490.00 |         |
| 4/8/79   | DEPOSIT     | 430.00 |           |           | 4920.00 |         |
| 4/9/79   | PAYROLL     | 210.00 | 261       |           | 4710.00 |         |
| 4/10/79  | RENT        | 25.00  | 262       |           | 4685.00 |         |
| 4/11/79  | UTILITIES   | 15.00  | 263       |           | 4670.00 |         |
| 4/12/79  | SALES       | 235.00 | 264       |           | 4905.00 |         |
| 4/13/79  | EXPENSES    | 190.00 | 265       |           | 4715.00 |         |
| 4/14/79  | DEPOSIT     | 440.00 |           |           | 5155.00 |         |
| 4/15/79  | PAYROLL     | 215.00 | 266       |           | 4940.00 |         |
| 4/16/79  | RENT        | 25.00  | 267       |           | 4915.00 |         |
| 4/17/79  | UTILITIES   | 15.00  | 268       |           | 4900.00 |         |
| 4/18/79  | SALES       | 240.00 | 269       |           | 514     |         |

SEE WORKSHEET #1

PRIORITY =  $A+B$  or  $A+C$  (lowest sum)

THE BACK OF THIS WORKSHEET FOR SIZES SHOWING EQUIPMENT LOCATION, IF DESIRED.

PRECAST CONSTRUCTION

EQUIPMENT INVENTORY WORKSHEET # 3

PAGE 3

SQUAD MEMBERS

AREA

| NO. | EQUIPMENT NAME AND DESCRIPTION                                | QTY | SIZE           | REMARKS  | SWT | DR | RR | BLAST | STRUCTURE | PRIORITY | REPAIR | REPAIR | REPAIR | HARDENING METHOD                               | MATERIALS REQUIRED                              | DRILLING  |
|-----|---|-----|----------------|--|-----|----|----|-------|-----------|----------|--------|--------|--------|--|---|-----------|
| 1   | PICKUP 3/4-TON  | 3   |                | STANDARD PICKUP                                | 0   | 3  | 3  | 0     | 4         | 0        | 10     |        |        | USE TO MOVE SPARES AND EQUIPMENT TO HOST AREAS | ONE DRIVER                                      | HOST AREA |
| 2   | EQUIPMENT BLDG 20 FT X 10 FT TILT-UP SLABS SECURED WITH BOLTS |     |                | CONTAINS HAND TOOLS FORM HARDWARE, POWER TOOLS | 0   | 4  | 4  | 0     | 2         | 2        | 10     |        |        | DROP WALLS BY CUTTING BOLTS AT CORNERS         | CUTTING TOOLS OR HACKSAMS OR SODAS AND WRENCHES |           |
| 3   | MOBILE TRAILERS/ OFFICES                                      | 2   | 10' 10' 20-35' | MOBILE HOME-TYPE TRAILERS ON BLOCKS            | 0   | 4  | 3  | 7     | 2         | 2        | 9      |        |        | REMOVE ROOF AND BRACINGS LEAVE STRUCTURES      | PICKUP OR PRIVATE CAR                           |           |
| 4   | FOREMAN'S OFFICE WOOD   |     | 12' 20'        | WOODEN STRUCTURE WITH ONE PARTITION            | 0   | 4  | 3  | 7     | 2         | 2        | 9      |        |        | REMOVE ROOF AND BRACINGS                       | PICKUP OR PRIVATE CAR                           |           |
| 5   |   |     |                |  |     |    |    |       |           |          |        |        |        |  |   |           |
| 6   |   |     |                |  |     |    |    |       |           |          |        |        |        |  |   |           |
| 7   |   |     |                |  |     |    |    |       |           |          |        |        |        |  |   |           |

RATING

PRIORITY = A+B or A+C (lowest sum)

DESCRIBE POSSIBLE COLLATERAL DAMAGE

COLLATERAL DAMAGE PROBABLE FROM 100-FT HIGH HEAPER AND ASSORTED LOOSE MATERIALS ALL OVER YARD

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION, IF DESIRED

PAGE # 1  
EQUIPMENT INVENTORY WORKSHEET

2006

| ITEM NO. | EQUIPMENT NAME AND DESCRIPTION  | QTY | SIZE                               | REMARKS  | SHIFT DRAIN TIME | RK | E | RR | BLAST | PRIORITY | PROJECT                  | PERCENT COMPLETED                   | ELAPSE TIME                         | HARDENING METHOD   | MATERIALS REQUIRED       | ESTIMATED COST PER UNIT | DATE |
|----------|---|-----|------------------------------------|--|------------------|----|---|----|-------|----------|--------------------------|-------------------------------------|-------------------------------------|--|--------------------------|-------------------------|------|
| 1        | AUSTIN WESTERN M20<br>ROUGH TERRAIN CRANE<br>3-TON CAPACITY<br>AFTER WEIGHT: 12 TONS  | 1   | H 10'-2"<br>W 8'-0"<br>L 24'<br>BA | FOUR-WHEEL DRIVE<br>AND STEER<br>SELF PROPELLED,<br>BALLOON TIRES<br>27-FEET BEAM  | 0 1/2            | 3  | 2 | 5  | 2     | -        | 7                        | <input type="checkbox"/>            | <input checked="" type="checkbox"/> | CLEAR CHANNEL<br>BETWEEN TWO LOCAL<br>BEAMS; REMOVE BRUSH<br>FROM WAREHOUSE; ROLL DOWN<br>INTERIOR; EXTEND<br>OUTWARD TO HARD SITE<br>TO HARD SITE | EARTHMOVING<br>EQUIPMENT | BULL<br>AL              | T12  |
| 2        | AUSTIN WESTERN M40<br>ROUGH TERRAIN CRANE<br>10-TON CAPACITY<br>AFTER WEIGHT: 40 TONS | 1   | H 10'-6"<br>W 9'-0"<br>L 24'<br>BA | FOUR-WHEEL DRIVE<br>AND STEER SELF-<br>PROPELLED; BALLOON<br>TIRES<br>45-FEET BEAM | 0                | 3  | 2 | 5  | 2     | -        | 7                        | <input type="checkbox"/>            | <input checked="" type="checkbox"/> | CLEAR CHANNEL<br>BETWEEN TWO LOCAL<br>BEAMS; REMOVE BRUSH<br>FROM WAREHOUSE; ROLL DOWN<br>INTERIOR; EXTEND<br>OUTWARD TO HARD SITE<br>TO HARD SITE | EARTHMOVING<br>EQUIPMENT | BULL<br>AL              | T12  |
| 3        | LINCOLN ARC<br>WELDER<br>AFTER WEIGHT: 400 LB   | 1   | H 4'<br>W 4'<br>L 8'<br>BA         | DON'T FORGET RED<br>PORTABLE (TRAILER)<br>TOWABLE                                  | 0                | 3  | 5 | 1  | -     | 6        | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/>            | MOVE TO HARD SITE<br>(IN CHANNEL);<br>REMOVE COVER PLATES<br>LAY ON GROUND AND<br>COVER WITH SOIL  | EARTHMOVING<br>EQUIPMENT | BULL<br>AL              | T12  |
| 4        | ECKO CEMENT<br>MIXER<br>0 QU. FT. CAPACITY<br>AFTER WEIGHT: 300 LB                    | 1   | H 4'<br>W 4'<br>L 6'<br>BA         | HAS OWN GAS<br>ENGINE -<br>PORTABLE (TOWABLE)                                      | 0                | 3  | 6 | 2  | -     | 8        | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/>            | MOVE TO<br>HARD SITE   | EARTHMOVING<br>EQUIPMENT | BULL<br>AL              | T12  |
| 5        | INTERNATIONAL SCOUT III<br>FOUR-WHEEL<br>DRIVE TRUCK<br>AFTER WEIGHT: 3,400 LB        | 1   | H 6'<br>W 6'<br>L 16'<br>BA        | FOUR-WHEEL DRIVE<br>HAS CAPACITY TO<br>TRANSPORT UP TO<br>10 PERSONS               | 0                | 3  | 5 | 2  | -     | 7        | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/>            | MOVE TO HARD<br>SITE<br>ROLL DOWN WINDOWS  | EARTHMOVING<br>EQUIPMENT | BULL<br>AL              | T12  |
| 6        | PORTA-POWER<br>HYDRAULIC JACKS<br>AFTER WEIGHT: 20 LB                                 | 2   | H<br>W<br>L<br>BA                  | 10,000 LB<br>CAPACITY EACH   | 0                | 3  | 6 | 4  | -     | 10       | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/>            | MOVE TO<br>HARD SITE   | EARTHMOVING<br>EQUIPMENT | BULL<br>AL              | T12  |
| 7        | GENERATORS 2 EACH<br>3,000 WATT AND<br>3,500 WATT<br>AFTER WEIGHT: 125 LB BA          | 2   | H 1'<br>W 1'<br>L 2'<br>BA         | DON'T FORGET<br>EXTENSION CORDS<br>HAND PORTABLE                                   | 0                | 2  | 4 | 2  | -     | 6        | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/>            | MOVE TO HARD<br>SITE<br>PUT IN CONCRETE<br>BLOCK BOX<br>COVER WITH SOIL  | EARTHMOVING<br>EQUIPMENT | BULL<br>AL              | T12  |

DESCRIBE POSSIBLE COLLATERAL DAMAGE

PRIORITY =  $A+B$  or  $A+C$  (lowest sum)

USE BACK OF THIS WORKSHEET FOR SKETCHES SHOWING EQUIPMENT LOCATION IF DESIRED

#### Section 4

### CONCLUSIONS AND RECOMMENDATIONS

The data obtained enable: an estimate to be made of change in vulnerability that can be expected from hardening; evaluation of differences between plant personnel and the originators applying the manual; reasons to be obtained for the performance differences as well as what to do to minimize them; comparisons to be made of how well estimates of the hardening effort (manpower, materials, time) coincided with that actually expended.

Table 2 summarizes the assessments indicating change in vulnerability as a result of hardening. Relocated plants are listed as invulnerable, based on the rationale that relocation will be to a designated host area where overpressures are presumed to be less than 2 psi. The difference between vulnerabilities estimated by SSI and by plant personnel are identified in the table. These were reconciled in the previous section discussion of each plant, and appropriate revisions or additions to the manual to minimize such differences in the future were identified.

Table 3 summarizes the assessments of estimated planning and execution times and manpower requirements for Phase II and compares these with the Phase II results. The two agree fairly well.

The work accomplished, to date, shows the self-help industrial hardening concept to be a feasible and practical strategy. Implementation of the hardening measures by plant personnel have been close enough to estimates to suggest paper exercises can provide a fair appraisal of expected time and manpower cost. In turn, the contribution of such expenditures to industrial survival could be significant in event of a nuclear attack. For example, if all plants could be raised from a vulnerability level of 2 psi (typically, the collapse pressure for the buildings) to 4 psi, then the relative areas

TABLE 2  
VULNERABILITY CHANGE DUE TO HARDENING AS AN INCREASE  
IN OVERPRESSURE EXPECTED BEFORE MODERATE DAMAGE RESULTS TO KEY EQUIPMENT

| Plant                                  | Before<br>Hardening<br>(psi) | SSI<br>Assessed<br>Improvement<br>(psi) | In-Plant<br>Personnel<br>Assessed<br>Improvement<br>(psi) | After<br>Hardening<br>(psi) |
|--|------------------------------|---|---|-----------------------------|
| Metal Caster                           | 2                            | 6                                       | 3   | 8                           |
| Electrical Equip-<br>ment Manufacturer | 2                            | 18                                      | —   | 20                          |
| Metal Stamping                         | 2                            | 14                                      | —   | 16                          |
| Steel Fabrication                      | 2                            | 8                                       | —   | 10                          |
| Food Processor                         | 2                            | invulnerable <sup>(a)</sup>             | —   | invulnerable <sup>(a)</sup> |
| Utility                                | ?                            | <sup>(b)</sup>                          |   |                             |
| Wood Products<br>Manufacturer          | 2                            | 18                                      | —   | 20                          |
| Small Job Shop                         | 2                            | invulnerable <sup>(c)</sup>             | (c)   | invulnerable <sup>(c)</sup> |
| Electronic Equip-<br>ment Manufacturer | 2                            | invulnerable <sup>(c)</sup>             | —   | invulnerable <sup>(c)</sup> |
| Precast Construction                   | 2                            | 5                                       | 15 <sup>(d)</sup>   | 17                          |

— Not attempted; SSI assessment only

(a) Mandatory food processing operations of this company all take place in rural areas, and only final "convenience" packaging takes place in this plant. Some of the equipment could be readily salvaged for other uses by other plants, but such analysis was outside the scope of the present study.

(b) Not analyzed or assessed because this utility's resources are already well dispersed geographically.

(c) Moved to host area, where overpressure is presumed to be 2 psi. If host area is not targeted, it may be assumed that these two plants have become "invulnerable".

(d) The proprietor was innovative, deciding to enter a new business in the post-attack environment wherein his most vulnerable equipment would no longer be needed, hence the discrepancy between assessed improvements.



TABLE 3  
COMPARISON OF ESTIMATED AND ACTUAL PLANNING AND EXECUTION TIMES

| Plant                                    | Planning Effort      |                            |                          | Estimated Phase II Effort |                  |                          | Actual Hardening Effort                |                   |                          |                           |     |
|--|----------------------|----------------------------|--------------------------|---------------------------|------------------|--------------------------|--|-------------------|--------------------------|---------------------------|-----|
|  | Man-Hours<br>Phase I | Number<br>of Men<br>II (a) | Elapsed<br>Time<br>(hrs) | Man-<br>Hours<br>of Men   | Number<br>of Men | Elapsed<br>Time<br>(hrs) | Man-<br>Hours<br>of Men<br>Used/Avail. | Number<br>of Men  | Elapsed<br>Time<br>(hrs) | % of<br>Plant<br>Hardened |     |
| Wood Products<br>Company                 | 4                    | 4                          | 2                        | 8                         | 500 (b)          | 24                       | 36                                     | Staged for movies |                          |                           | 20  |
| Small Job Shop                           | 15                   | 1                          | 1                        | 16                        | 12               | 2                        | 6                                      | 14                | 2/2                      | 7                         | 100 |
| Electric/<br>Electronics<br>Manufacturer | Unknown              |                            |                          | Not estimated (c)         |                  |                          | 64                                     | 8/16              | 8                        | 100                       |     |
| Precast<br>Concrete Yard                 | 12                   | 3                          | 1                        | 15                        | 16               | 4                        | 7                                      | 24                | 4/6                      | 10                        | 100 |

- (a) Logistic planning for hardening operations.
- (b) One hundred hours if sandbags were filled in advance; forty hours if equipment skidded into a ditch, covered with heavy plastic, and protected with backfill.
- (c) Four men required five days to relocate entire plant and return it to full production. It was estimated that evacuation required forty percent of this effort.

subjected to these two overpressures is a measure of damage avoided; that is, the area subjected to 4 psi is only 38% of the area subjected to 2 psi, and the area reaching the new damage level is 62% less than before. If the vulnerability could generally be raised from 2 psi to 8 psi (as appears feasible so far), then the area of damage is reduced by 84% (i.e., to 16% of the original area). If industry were uniformly distributed in the risk area, then according to these calculations, the portion of industry saved from serious damage by hardening (to 4 psi, or to 8 psi) could be 62% and 84% respectively.

The implications are that over 80% of that portion of U.S. industry hardened could be recovered, post-attack, and placed in operation within a short period (perhaps a matter of weeks). Just what portion of a plant or of industry might be hardened is dependent on how successfully priorities are established within each plant and on how many plants, nationwide, respond. Attitudes and decisions about hardening (e.g., the decision at one plant to abandon an old line of business in the post-attack world) will affect the final outcome, and certain capabilities might be in short supply. More preparedness studies involving industry will be required to answer these kinds of questions. One that appears very important to consider at the outset involves the likely circumstance that selected industries would be targeted as an attack strategy to create a bottleneck for the rest.

At the plants visited, all were well aware that disruption of electricity and fuel supplies could negate the benefit achieved by their hardening effort. Some raised the question whether this would not make electric utilities and refineries prime targets. Still, more than half have thought seriously about standby electric power systems as a means to deal with current energy problems and some thought such systems could improve the emergency or post-attack situations. None of these plants had such a system, primarily because they lack the expertise in-house and do not have faith that outside consultants can make better decisions, which are a complex mix of technical, economic, and political factors.

Examining the question of standby units from the opposite end, a supplier of motor generator units provided some interesting information. Questions about standby units have increased fivefold since the winter of 1973-1974 and the average size of interest has increased threefold. There is little doubt that a very strong concern exists for standby power alternatives. It would seem, therefore, that this interest coupled with the new emphasis on cogeneration could provide the impetus throughout the United States to develop a well dispersed backup capability for electric power generation. Moreover, there is no *a priori* reason why these units could not all be installed in easily hardened facilities capable of taking 40 psi or more. If this backup generation capability were to be developed as a serious effort, then a backup fuel supply would become the major difficulty.

The immediate post-attack fuel supply problem is likely to be the loss of refineries. Thus, over the short term, fuel refining in large refineries would probably come to a halt. In this case, whatever refining might be done in the immediate post-attack era would likely have to be accomplished in primitive micro-refineries. Because preparedness planning could greatly enhance this as a workable expedient, a preliminary analysis of this option was conducted to see what the micro-refinery scenario might entail. The analysis has been included as Appendix B.

In summary:

- o Preparedness planning can be expected to enhance survival in a post-attack environment very significantly.
- o A hardening manual has been developed for industry to expedite its self-help planning.
- o The manual has been tested at industrial plants and found workable.
- o With advance planning, hardening can be implemented in one to several days.
- o Improvements to the manual have been recommended, and these

will be studied and appropriate changes made in the future.

- o Industries' dependency on electrical power and fuel is critical.
- o Expedient power and fuel alternatives must be developed, must be obvious to industry to make hardening seem worthwhile, and must not be disruptable.

Testing of hardening concepts needs to be carried beyond testing the feasibility of implementing; field testing should be applied to verify outcomes. Industry needs a repertoire of hardening options that are fully verified for outcome (when implemented by novices!) and described pictorially in the manual. To reduce the amount of field testing required, shock tube studies should be applied to verify analytical methods used to calculate equipment vulnerabilities and to pinpoint the field testing required. Nevertheless, statistical data from a dozen or more tests of a dozen different types of industry are desirable.

To provide a frame of reference for estimating the importance of supporting a serious effort such as described, (perhaps one billion dollars a year) U.S. industry is worth close to one trillion dollars in monetary terms. In terms of world position, this monetary measure is totally inadequate. If the U.S. were to make the choice between losing its world position, or spending a billion dollars, there is little question. We are already spending 150 billion a year to prepare for the common defense. Yet, in the face of a nuclear attack, perhaps the most important facet of U.S. defense is industry, it must survive to supply defense materiel and survival and recovery equipment. The important task of safeguarding industry might be considered worth more than 0.5% - 1% of the defense budget.

APPENDIX A  
Encounters With Potential  
Industrial Hardening Participants

## EXAMPLE # 1

### "Typical" Encounter With Potential Industrial Hardening Participant

Original appointment made by intermediary with contacts in company. Visitors were C. Wilton, J. Zaccor, Bill Sugg, who met with the owner of a food processing plant.

Started with small talk. Owner told just a little about his company, then launched into a discussion of "60 Minutes" regarding a segment on \$16 million loaned, at farm rates, to a multimillionaire.

C. Wilton: Discussed SSI's research into helping industry survive a disaster: earthquake, tornado, hurricane, etc.

Explained SSI compiled a manual that industry can use to develop preparedness plans.

Made point need practical testing of the manual.

Cautioned that manual slanted towards nuclear attack — because started out funded by DCPA, now FEMA . Discussed broader FEMA role; i.e., concerned with any disaster — so SSI attempting to make manual more generalized. Also need to have some of industry try to apply it. Hence, arranging visits to plants where there is an indication of potential interest.

Owner: What do you need/want?

SSI:

- a) Permission to go through the plant and make an assessment of vulnerability according to our manual.
- b) Pictures, which we will use for our analysis, then return to you for approval of our use in reports.
- c) Perhaps a member of your staff could go through several booklets in

the manual — [then gave a quick rundown of booklets]. What we need is someone to speak his thoughts and comments into a recorder that we would leave, along with the manual, for that purpose.

d) Finally, we hope to find several plants willing to go completely through the planning stage and perhaps carry out a dry-run hardening exercise.

Owner: What does that mean?

SSI: Well, it could be anything from carrying out exercises to protect one key piece of machinery to protecting the whole plant. So far, only completely staged tests have been performed — and by experts in weapons effects. What we really need is to find out what can be done by non-experts and how long it takes.

Owner: Well, I guess my son could show you around the plant. You can take pictures if you want. Let me get Tony.

SSI: What we'd like to do is sort of start where the product comes into the plant and follow it through — then get a feel for how to protect key equipment.

Tony: Well, if you walk over here I can show you how it all starts. We get (right now, tomatoes) for processing, whatever — depends on the seasons, etc. Anyway, it comes in here in trucks — you ever see them on the road in the valley? — loaded with tomatoes. Well, they bring 'em right up here and they are dumped in there and . . . . Then, if you come over here, . . . . Then they go . . . to get . . . . etc.

SSI: Is there anything in this process line that you could do without?

Tony: Well, I don't think we could do without any of it — or we wouldn't have it. It's all important to our operations.

SSI: Well, suppose there were an emergency or something: Say, the equipment got damaged, what do you do; that is, how do you handle it?

Tony: That depends on what the damage is — For example we can call up at a moment's notice and expect to get a 100-horsepower boiler onsite and operating within 8 hours.

SSI: Well, we were thinking of maybe a fairly large-scale disaster — where the whole state is affected, or maybe even the entire United States, like with a nuclear attack. If that were the case, is there anything here you could maybe do without? — so that you could concentrate on trying to save just a few really important items?

Tony: Um, gee — a nuclear war? I guess everybody is affected — Yeah, we wouldn't need anything here then. We could do without all of it. People would be hungry, then. What would they care about whether the cores were removed — or the skin taken off? You see, all we do here is sort of cosmetics. We make it attractive on the table — and most of what we do is condiments, with probably almost no nutritional value. People will need the basics, not condiments. Now, we could pasteurize milk instead of processing tomatoes, and we could can more nutritional things like fruits instead of condiments. All that stuff there — you know where I showed you the tomato trucks come in — we still wouldn't need any of it. Who would care about skin being on the fruit? No. The heart of what would be needed are the evaporators and the canning line; all the rest of it could go. We probably need the conveyors here, though — to get the stuff from the evaporator to final packaging.

SSI: Well, one of the things that will happen is that a lot of people won't have work because their plant is gone — so there might be plenty of manual labor available with nothing better to do than preserve food.

Tony: Yeah, that's probably so — I hadn't thought of that. I expect just about everything would be different.

SSI: You seem to have lots of cans — You could convert some to pails; couldn't people move stuff around in pails?

Tony: Sure, that's probably easy enough to arrange if you have the people and they are willing. I guess anybody would probably be willing if it meant the difference between getting fed or not — even if it's just apples.

SSI: Well, you seem to have the idea of what we need to consider all right. Do you think you could look at this manual we have made up and



see if you can follow it — what questions come to mind; how you might do it differently — things like that?

Tony: I could, but we're into the heavy tomato season now and there isn't much time for it. I couldn't get to it for quite a while.

SSI: Well, we know it is time-consuming and we are hoping that we can uncover enough immediate benefits in the way of advance planning for just about any emergency to make it worthwhile — but to do that we are going to need people to review it and give us back some ideas. Because that takes time, we are willing to pay whoever does it for their effort.

Tony: I wouldn't mind doing it, but canning is seasonal and when it's on it pretty well takes all the time there is.

SSI: Could we leave the manual and ask you to work it in when you get a chance?

Tony: Well, I suppose so. The thing is, I couldn't promise you when that might be.

SSI: That is understandable. We'll leave you this copy and then when you do have some time, it will be handy.

## EXAMPLE # 2

### Commentary on Crisis Relocation Industrial Hardening Plan

Taped by Electronics Plant Manager

#### Booklet No. 1

My overall impression, as a manager of a business, to Booklet No. 1 is that more effort should be made to put the business that is being addressed in perspective to the total problem. For example, the first thing I want to know is whether or not I would be a critical industry. The next thing is in what area is my plant located — am I in a high-risk or a low-risk (host) area? Setting the context for a manager reading this material is very important; otherwise it all seems very overwhelming and almost unrealistic to consider that all of this hardening could be done in a 72-hour warning period.

The next thing I would want to know is how I would go about implementing or even thinking about the management planning required for a hardening program. I realize that the Booklets 2 through 10 or so answer this question, but an overview of the process would be important in the first part to give me a feeling that it is actually "do-able". The six drawings at the end of Booklet No. 1 depicting the different ways to protect against blast of different magnitudes are very interesting to me as a former engineer; introduced this early in the information tends to make me believe the whole thing is unrealistic. I can't imagine putting in shore posts if it's actually only a 72-hour warning; on the other hand I can't imagine putting in shore posts right now on the assumption that some day we'll have an emergency.

#### Booklet No. 2

Since this is my first exposure to this entire concept, I find Booklet No. 2 rather mind-boggling. First, it involves an apparent degree of responsibility for the dependents of all of the work force that I would not

have thought practical for a 300-man company. For purposes of studying a possible relocation, our company had actually generated a map with pins designating employee home locations. Our plant was located, as you might expect, in the center of the distribution of the employees' homes. We had employees who lived in every direction from the plant and commuted typically 30 minutes and in many cases one to one and a half hours. In our specific case, we had employees living in San Francisco, Santa Cruz, Gilroy, Fremont, and Berkeley, with our plant located in Mountain View. It is hard for me to imagine how it would be practical to evacuate. . . .

The general approach outline started on page 3 of Booklet No. 2 strikes me initially as a little complex to carry out under the deadline of a 72-hour evacuation notice. It might have to be simplified to something like having everyone who lives in Redwood City gather in the left-hand corner of the plant and work out a plan for themselves. Also, it seems to me that it is important whether the plant is essential or non-essential in that, if it is non-essential and is going to be shut down, there would be no need to try to move all of the dependents into one place. Rather, the facility would be shut down and people would be free to leave and take care of their families under Civil Defense instructions.

The other question that comes to my mind is how does my company pick its host area?

#### Booklet No. 3

Page 5, Item 3.— It should be more specific exactly what the crews that are being sent out are to accomplish. I assume they are to do the work outlined on the right-hand side of page 2 and the top of page 3.

Page 7. — Under decision factors, it mentions again that vital records can be moved from the risk to the host area, but so far I haven't the foggiest idea of what my host area is, or how I would go about figuring out what my host area is supposed to be.

Booklet No. 4

It seems to me that the teams sent out for resource inventory could somehow be combined with the teams sent out to perform the work outlined on page 5 in Booklet No. 3. The resource inventory might even come before the work parties go around trying to conduct protective house-keeping activities. In the time frame talked about, I don't see how you can have time for teams for resource inventory and filling out those forms, and also work parties for protective hardening and filling out the forms at the end of that booklet.

Booklet No. 5

My reaction is it's far too complex. If it wasn't done in advance, there would be no way to get the people to fill out that kind of detailed inventory in a one or two hour period when they have just received a 72-hour notice to evacuate.

My overall reaction to reading all of the booklets is that the plan does not seem realistic to implement under a 72-hour deadline. The forms are too complicated for the time period involved. I have a lot more comments and thoughts on the subject, but I'd like to go over them in person, because I'm running out of tape.

EXAMPLE # 3

Commentary of Proprietor at Precast Concrete Plant  
Participating in Phase II

Booklet No. 1

After reading through the whole manual twice, I believe I would throw all the booklets excepting Booklet No. 1 away. I got the picture clearly from this management booklet, while the rest just consumed time and did not add enough for me to really warrant spending it.

Booklet No. 2

I automatically think of those people that I believe would make all the difference to survival — and they are the ones that would also help establish an operating company under whatever conditions turn up. We're small, but we could set up to handle 60% of our crew and their entire families. I have property in a good safe area, and chances are that with advance notice we might all relocate there.

Booklet No. 3

I wouldn't bother with protective housekeeping — I'd just move what I wanted to protect out to a place where that isn't a problem; it would be a hell of a lot faster. I'd guess we could do it in an hour if we were prepared, whereas it would take days to clean up around here.

Who needs records? Who is going to be in a position to pay old bills anyway? No, I'd start from a clean slate and move faster than the old conservatives, probably wind up owning a piece of their action as a result of bailing them out. I wouldn't do it for money because what would that be worth? Who would be using it? Not me! Barter and equity are the only way to go.

Booklets No. 4 to 8

I know what I need and I know I don't need complicated schemes like these to tell me. It's all pretty simple if you read Booklet No. 1, and part will be luck anyway. I can do everything that has to be done in one day and I can keep right on operating after it's set up. I'll have everything hardened when not in use, and one hour is all I need to respond at any time. My site is located only a few hundred yards from the intersection of two major highways, one an interstate, so that when it's over I can get most anywhere I might be needed in a hurry.

## APPENDIX A SUMMARY

When you read these responses it appears that the viewpoints are poles apart, an indication that attitudes and opinions make up the major reason for differences — not necessarily the manual. There is no doubt that the manual can be improved by incorporating a great many of the suggestions made, but, of course, when the suggestions are diametrically opposed this is not feasible.

The comments in this appendix show also that there is a great deal of innovative talent that will come to the fore when needed. Acceptance, a will to take action, and an ability to relate to different circumstances seem to lie at the heart of this innovative response.

APPENDIX B  
Post-Attack Petroleum Refining  
(and Production) from Crude Oil



## POST-ATTACK PETROLEUM REFINING (AND PRODUCTION) FROM CRUDE OIL

### BRIEF HISTORY

Petroleum refining began in the United States and Russia in the second half of the 19th century, following the discovery of "rock oil" in Pennsylvania in 1859. In the earliest refineries, simple stills separated crude oil into impure gasoline, kerosene, lubricating oil, and fuel oil fractions. The first big advance in petroleum production technology came in 1913 with the introduction of thermal cracking. This process consisted of taking the heavier fractions after distillation and heating them under pressure, thereby cracking, or splitting, their large molecules into the smaller ones that form the light, more valuable fractions. During the 1930's and World War II, refining processes involving the use of catalysts led to further improvements in the quality of fuels and increased their supply. These included catalytic cracking, polymerization, alkylation, and isomerization. The 1950's and 1960's brought a large-scale demand for jet fuel and for high-quality lubricating oils. Catalytic reforming was established as the leading process for upgrading automotive motor gasolines for use in the higher compression engines. Hydrocracking, accomplished by the addition of hydrogen during refining, also improved the crude-oil fractions.

### TYPES OF CRUDE

Crude oils vary widely in boiling range and composition. Fig. B-1 shows the proportions of the products obtained by distillation of six typical crude oils, ranging from West Venezuelan heavy crude to the light Algerian crude, Hassi-Messaoud. The percentage of lighter products (gasoline and naphtha) increases to the right of the chart. Middle distillates (which include kerosene and diesel) also increase, while fuel-oil content diminishes.

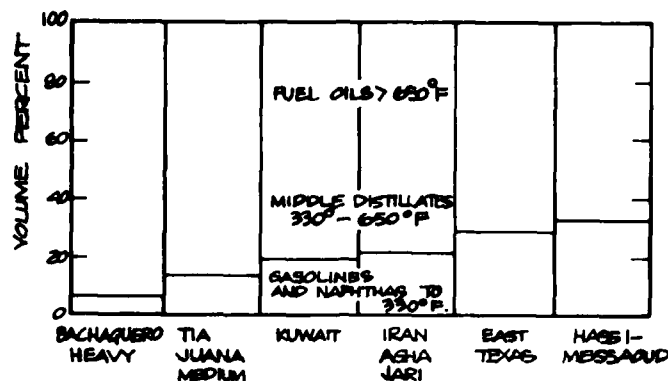


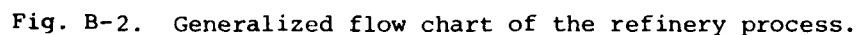
Fig. B-1. Proportions of the products obtained by distillation of six crude oils.

Four main types of hydrocarbons are present in crude oil: normal paraffins, isoparaffins, cycloparaffins (also called naphthenes), and aromatics. Some crude oils, such as Pennsylvanian, consist mainly of paraffins. Others, such as the heavy Mexican and Venezuelan crudes, are predominantly naphthenic and are rich in asphalt. The various hydrocarbon compounds that are mixed together in crude oil have different boiling points, but apart from the lightest, the differences between the boiling points of neighboring members in the rising scale of molecular weight are so small (only fractions of a degree) that they cannot be separated by ordinary distillation. Fortunately, separating is not usually necessary; most common petroleum products consist of mixtures of compounds where boiling points fall within a specified range.

Typical boiling ranges (at 1 atmosphere) are:

|                 |                             |
|-----------------|-----------------------------|
| motor gasoline: | 75° - 300°F (25° - 150°C)   |
| kerosene:       | 300° - 450°F (150° - 230°C) |
| diesel oils:    | 450° - 650°F (230° - 340°C) |
| fuel oils:      | above 650°F (340°C)         |

A generalized flow chart of a modern refinery process is shown in Fig. B-2 below.



### Separation Into Components

B-3

oil distillate side stream at about 540°F; and a bottoms product at about 600°F. Fig. B-3 shows a fractional distillation unit.

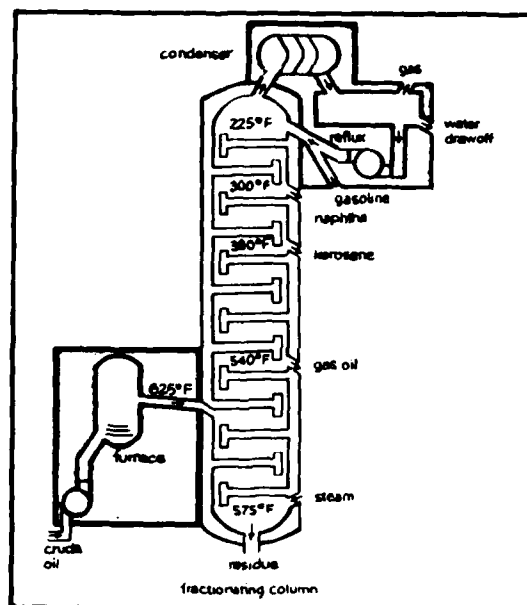


Fig. B-3. General operating principles of a fractional distillation unit.

Vacuum distillation resembles fractional distillation, except that larger diameter columns are used to maintain comparable vapor velocities at the reduced pressures; the equipment is similar.

Superfractionation is an extension of fractional distillation employing columns with a much larger number of trays (e.g., 100) and reflux ratios exceeding 5:1.

Absorption and stripping are processes used to obtain valuable light products such as propane/propylene and butane/butylene from the gas vapors that pass out of the top of the fractionating tower.

Solvent extraction processes are used primarily for the removal of constituents that would have an adverse effect on the performance of the product in use.

Adsorption. Silica gel is used to separate aromatics from other hydrocarbons, and activated charcoal is used to remove liquid components from gases.

#### Alterations of Molecular Structure

By changing the molecular structure of the components of crude oil, it is possible to convert less valuable hydrocarbon compounds into those in demand.

Thermal cracking is typified by processes in which kerosene or gas oil materials are converted by heating to 850° - 1000°F (450° - 540°C) at pressures of 250 to 500 psi. This produces gasoline of about 70 octane number.

Thermal reforming alters the properties of low-grade components such as naphthas by converting the molecules into those of higher octane number (and therefore lower molecular weight).

Use of a catalyst in the cracking reaction increases the yield of improved quality products under much less severe conditions than thermal cracking (850° - 950°F and 10 to 20 psi). Zeolitic or molecular sieve-base catalysts are used.

Catalytic reforming uses catalysts to mold molecular structure into desirable forms without the formation of unwanted heavy products and coke.

In polymerization gaseous hydrocarbon molecules are induced to combine, or polymerize, into molecules of two or more times the molecular weight, forming a material that performs well as a motor fuel.

The alkylation reaction also achieves a longer chain molecule by the combination of two smaller molecules, one being an olefin and the other an isoparaffin.

Isomerization converts the more abundant normal butane into isobutane as well as pentane and hexane into the corresponding isoparaffins.

Hydrocracking is used for producing gasoline or middle distillates from heavy gas oils, for converting residues into lighter oils, or for producing liquefied petroleum gases from straight-run naphthas. By cracking these in the presence of hydrogen and a catalyst, valuable products are obtained without simultaneous formation of coke and large quantities of gas.

#### Purification Processes

Sulfuric acid treatment removes sulfur by dissolution, polymerizes highly reactive hydrocarbons and neutralizes nitrogen bases. Asphaltic constituents and easily oxidizable compounds are also removed.

Sweetening processes convert evil-smelling and corrosive mercaptans into relatively innocuous disulfides.

Hydrotreatment processes are used primarily for sulfur removal from gasolines, naphthas, kerosenes, and diesel oils.

#### POST-ATTACK PROCESSES

Several simplified processes for petroleum distillation in a post-attack recovery scenario can be devised. A few of these are described here.

##### 1. Simple Batch Distillation

This is a distillation process in which a batch of material is charged to a still, vaporization is caused by the suitable application of heat, and the vapors are removed continuously, as formed, with no partial condensation of the vapors or refluxing of condensate to the still.

Fig. B-4 presents a schematic flow sheet of the process.

The still (distillation pot) can be made from practically any large vessel used in industry, examples being railroad cars, LNG storage tanks,

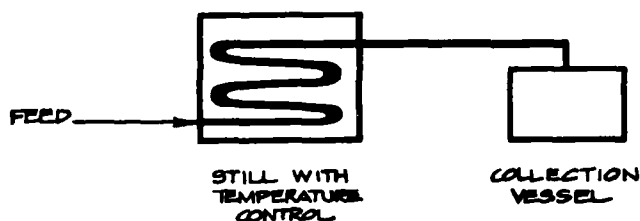


Fig. B-4. Schematic flow sheet of batch distillation.

autoclaves used in laminated glass production, reaction vessels used in the chemical industry, etc. These should be thick-walled (more than 1/4-in. thick) and preferably of stainless steel construction with a large surface-to-volume ratio, in order to increase the heating efficiency. Care should be taken to make sure that the still is accessible to humans for removal of the residues. From this point of view, a cylindrical autoclave with a side door would probably be most desirable.

The temperatures required are easily achieved with wood fires. Alternative sources of heat available are the light fractions (butane, propane, pentane) and the residues left in the distillation still. When using fuels for direct heating, due care must be given to safety. Inattention can cause the flames to light the feed, or any one or more of the products. Spilled petroleum must be thoroughly cleaned up at all times. A full description of the safety aspects of direct-flame heating will be deferred to a more detailed study.

The collector vessel can be improvised from practically anything that will not be dissolved by the liquid fractions; e.g. 55-gallon drums, dumpsters, reactor vessels. Tank cars might prove to be ideal since they are already on wheels, and can be conveniently changed for collection of different distillates.

Pipe connections between the still and collector vessel should be at least 4 in. in diameter, and preferably larger. Condenser coils can be

made from copper tubing. This should preferably be wound in several sections, with a valve to adjust the flow rates so that the cooling rate can be adjusted according to the distillate to be collected.

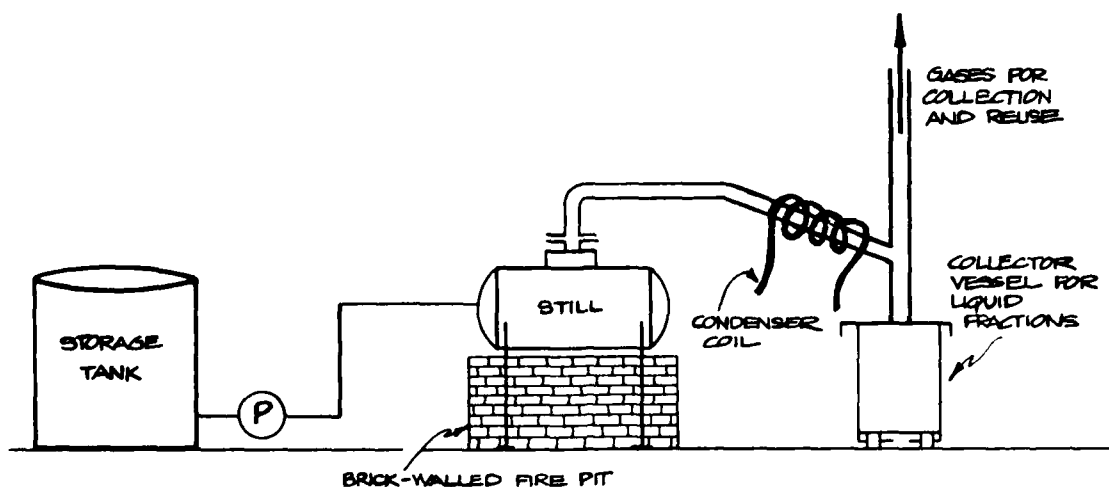


Fig. B-5. Simplified process diagram for batch distillation.

The evaporation rate of the desired fractions will be dependent on

- (1) Heat transfer from flame (fire pit) to crude in distillation pot,
- (2) Partial pressure of distillate,
- (3) Type and composition of crude,
- (4) Operation pressure (assumed atmospheric),
- (5) Surface area of crude in the distillation pot.

Sample Calculation. — A detailed discussion of batch distillation calculations is beyond the scope of this work. However, a simplified calculation scheme using the Rayleigh Equation is illustrated here. This calculation scheme is suited to differential vaporization and is based on the relative volatilities of the components.

Let A, B, C, D, etc. represent the total moles of the respective components in a multicomponent mixture. If a differential amount of the



mixture is vaporized:

$$\frac{-dA}{dB} = \frac{y_A}{y_B} = \alpha \frac{x_A}{x_B} \quad (\text{Eq 1})$$

where  $x$  is the mole fraction (or weight fraction) of the more volatile component in the liquid, and  $y$  is the mole fraction (or weight fraction) of the same component in the vapor in equilibrium with the original liquid.  $\alpha$  is a constant which is normally independent of temperature.

$$x_A = \frac{A}{A+B+C+D} \quad x_B = \frac{B}{A+B+C+D} \quad (\text{Eq 2})$$

Therefore: 
$$\frac{-dA}{dB} = \alpha \frac{A}{B} \quad (\text{Eq 3})$$

$$\text{Integrating } \ln \frac{A_1}{A_2} = \alpha \ln \frac{B_1}{B_2} \quad (\text{Eq 4})$$

where  $A_1$  = total moles (or weight) of component A in the original mixture

$A_2$  = total moles (or weight) of component A remaining in the residual liquid after the batch-distillation operation

$B_1$  = total moles (or weight) of component B in the original mixture

$B_2$  = total moles (or weight) of component B remaining in the residual liquid after the batch-distillation operation.

The variation of  $\alpha$  under the conditions of the distillation should be investigated before applying Equation 4.

The mixture of fractions assumed in the crude is shown in Table B-1. This is similar to some compositions of Texas crude. Average molecular weights based on average boiling points of gasoline, kerosene, and diesel have been assumed, and are shown in Table B-2 and Fig. B-6.

Table B-1: Assumed mixture of fractions

| Fraction | Weight (%) |
|----------|------------|
| Gasoline | 16         |
| Kerosene | 33         |
| Diesel   | 14         |
| Residue  | 37         |

Table B-2: Average boiling points and molecular weights

| Fraction | Boiling Point Range (°F) | Average Boiling Point (°F) | API Gravity | Average Molecular Wt. |
|----------|--------------------------|----------------------------|-------------|-----------------------|
| Gasoline | 75 - 300                 | 187°F                      | 70 - 52     | 85                    |
| Kerosene | 300 - 450                | 375°F                      | 52 - 40     | 160                   |
| Diesel   | 450 - 650                | 550°F                      | 40 - 30     | 240                   |
| Residue  | > 650                    |                            |             | 310                   |

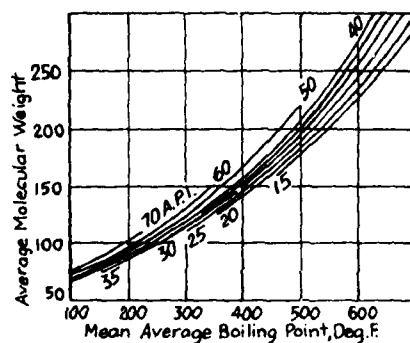


Fig. B-6. Molecular weights of petroleum fractions as a function of boiling point and specific gravity.

On the basis of 100 kg of the original mixture, the initial calculation is done for distilling out gasoline. Similar calculations can be repeated for the kerosene and diesel fractions. An initial distillation temperature of 220°F is assumed, with the final temperature (at condensation) at 70°F. The vapor pressures have been estimated with Fig. B-7, and are tabulated in Table B-3.

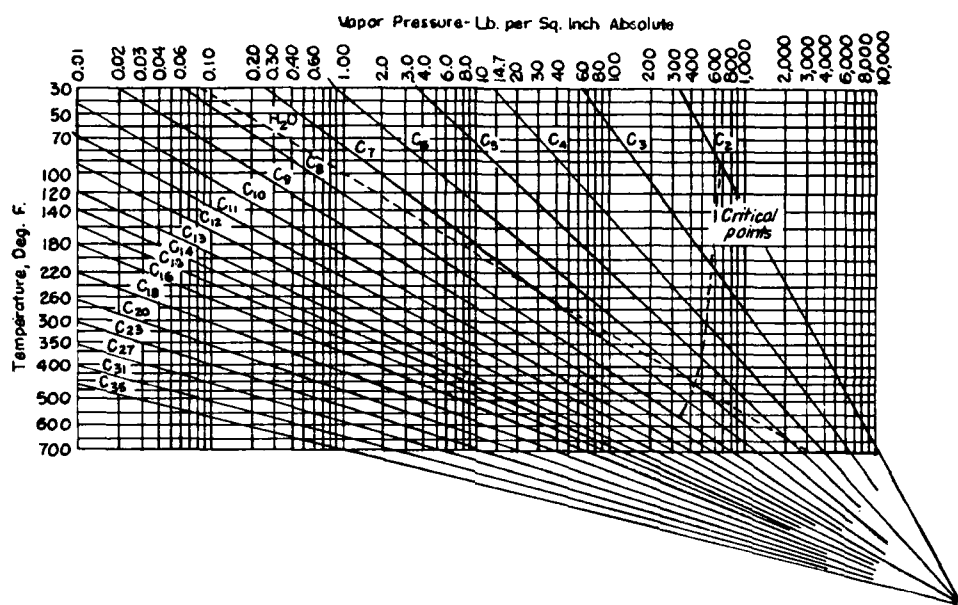


Fig. B-7. Cox chart for vapor pressures of normal paraffin hydrocarbons.

Table B-3: Vapor pressures of the fractions at 220°F and 70°F

|                         |       | Gasoline | Kerosene | Diesel | Residue |
|-------------------------|-------|----------|----------|--------|---------|
| Weight (%)              |       | 16       | 33       | 14     | 37      |
| Average Molecular Wt.   |       | 85       | 160      | 240    | 310     |
| Moles                   |       | 0.188    | 0.206    | 0.058  | 0.119   |
| Mole Fraction           |       | 0.329    | 0.361    | 0.102  | 0.208   |
| Vapor Pressure at 220°F | psi   | 42       | 0.9      | 0.02   | 0.001   |
|                         | mm Hg | 2171     | 46.5     | 1.03   | 0.1     |
| Partial Pressure mm Hg  |       | 714      | 16.8     | 0.11   | 0.01    |
| Vapor Pressure at 70°F  | psi   | 2.7      | 0.01     | --     | --      |
|                         | mm Hg | 139.6    | 0.52     | --     | --      |

$$\text{For } \frac{C_{\text{gasoline}}}{C_{\text{kerosene}}} : \alpha_{220} = \frac{46.5}{2171} = 0.0214$$

$$\alpha_{70} = \frac{0.52}{139.6} = 0.0037$$

$$\alpha_{\text{avg}} = 0.0126$$

Assuming that 90% of the kerosene is to be left in the distillation pot (i.e., 10% goes over with the distillate), and using Equation 4:

$$\log \frac{\text{Initial kerosene}}{\text{Final kerosene}} = 0.0126 \log \frac{\text{Initial gasoline}}{\text{Final gasoline}} *$$

$$\log \frac{33}{29.7} = 0.0126 \log \frac{16}{x}$$

$$\log \frac{16}{x} = (\log \frac{33}{29.7}) / 0.0126 = 3.6315$$

$$x = 16 / 10^{3.6315} = 0.0037 \text{ kg}$$

Therefore, percentage of gasoline left in liquid =  $(0.0037/16) \times 100 = 0.02\%$

If 95% of the kerosene is to be left, then a reiteration of the above calculation yields: 0.02730 kg gasoline left in the liquid. This is equivalent to 1.7%.

The yield of gasoline is above 95%. But one must be warned that these calculations are extremely simplified, and that crude fractions could change quite a bit from region to region.

## 2. Continuous Distillation

Batch distillation is the simplest of installations. The next step is the arrangement of such a still for continuous or semi-continuous operation. The first step to take would be to increase the distillation temperature

---

\* Note: The natural logarithm (ln) of Eq 4 has been converted to logarithm of base 10 (log) for ease of handling.

to around 600°F, and increase the number of collection vessels from one to three for the gasoline, kerosene, and diesel fractions. A schematic flow chart of such a process is shown in Fig. B-8.

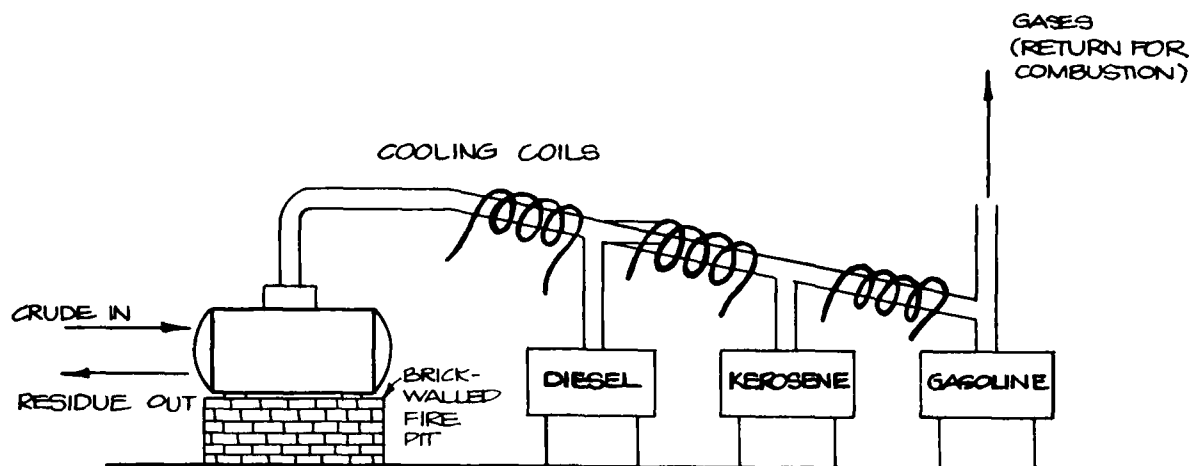


Fig. B-8. Schematic of continuous distillation.

The vapors will be cooled in sections to permit the condensation of the fractions one at a time. The gaseous and residue fractions can be used for heating of the crude. A sophistication to this process can be added by using the raw crude to cool the vapors, the crude becoming heated in the process. This can be achieved by using conventional pipe heat exchangers arranged suitably. Auxiliary cooling with water might be required. As the volume of production increases, the cooling rate achievable with cooling coils will be limited, and the transition to heat exchanger type condensers cannot be avoided. The use of several truck radiators is also conceivable. Compared to batch distillation, more condensers and piping are required. The same distillation still could be used.

Semi-continuous operation of such a unit calls for raising the temperature gradually, and collecting the respective fractions. The still will then have to be emptied and recharged.

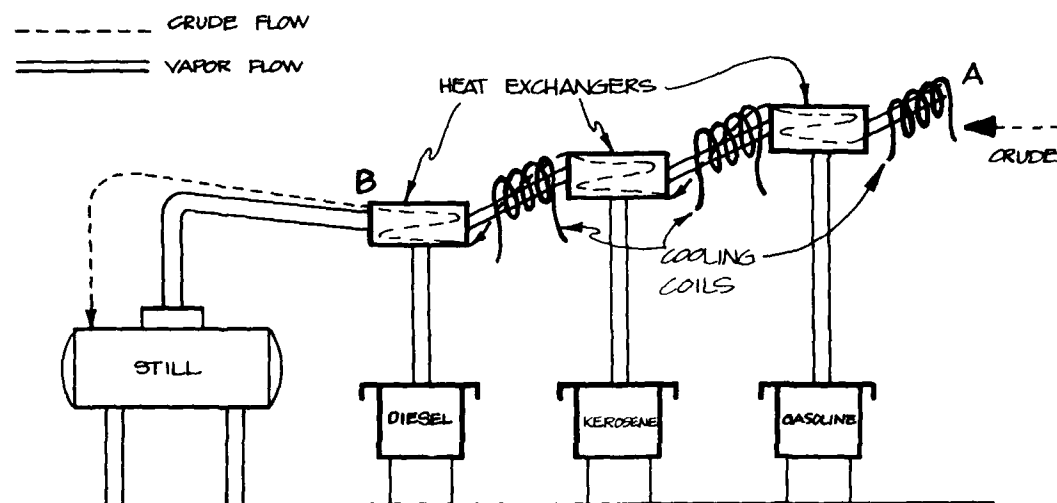


Fig. B-9. Continuous distillation using heat exchangers for condensing vapors and heating crude.

### 3. Continuous Distillation with Fractionating Tower

Distillation may be so conducted that fractionation of products results to a greater or lesser degree, but complete separation of several products from one liquid by one distillation is impossible without auxiliary fractionating equipment. A schematic flow diagram of a distillation still with fractionating tower is shown in Fig. B-10.

An ideal installation that could be modified for fractionating could be a boiler with its stack. The inside of the stack will have to be lined, and trays installed for the fractionation. The space between the trays should preferably be filled with perforated sheets (because of their light weight) or some other suitable material to promote nucleation of the vapors. Holes will have to be made in the side wall for extraction of the condensed fractions. The boiler can be modified into a pipe still for heating the crude.

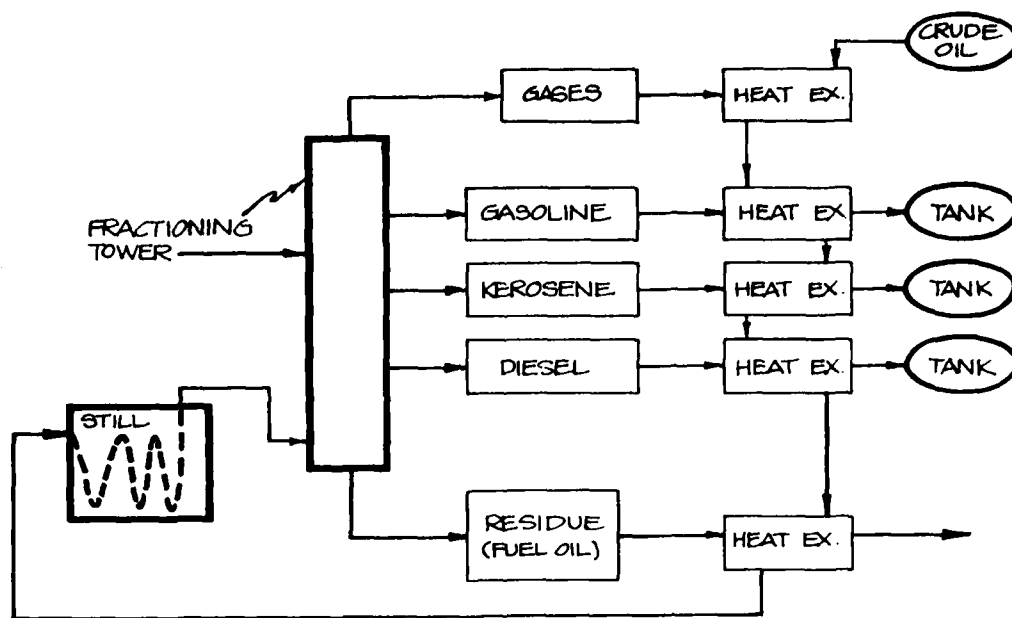


Fig. B-10. Petroleum distillation with a fractionating tower.

Alternate means of erecting a fractionating tower could include:

- (1) Erect concrete pipes (4 ft diameter) vertically, and line the inside with steel sheets
- (2) Use 3-ft diameter steel pipes (of the type used in trans-continental pipelines). If the expected service life is short, water pipes might be adequate.
- (3) Use tank car shells and connect them vertically.
- (4) Other options will include vertically connecting cylindrical vessels of about 3-ft diameter to give a sufficient height (about 30 ft).

The height requirements will depend on flow rates, heat distribution, etc. Temperature control along the height of the fractionating tower is extremely important. If there are problems with temperature control, a less elegant but surer method would be separation by successive flash

fractionation, as shown in Fig. B-11. In this scheme, the lowest boiling product is vaporized in tower No. 1 by reboiler heat at the bottom of tower No. 1, and successively higher and higher boiling materials are removed in the remaining towers. This system offers the flexibility of being able to add on more towers, along with easier temperature control, as more products are desired.

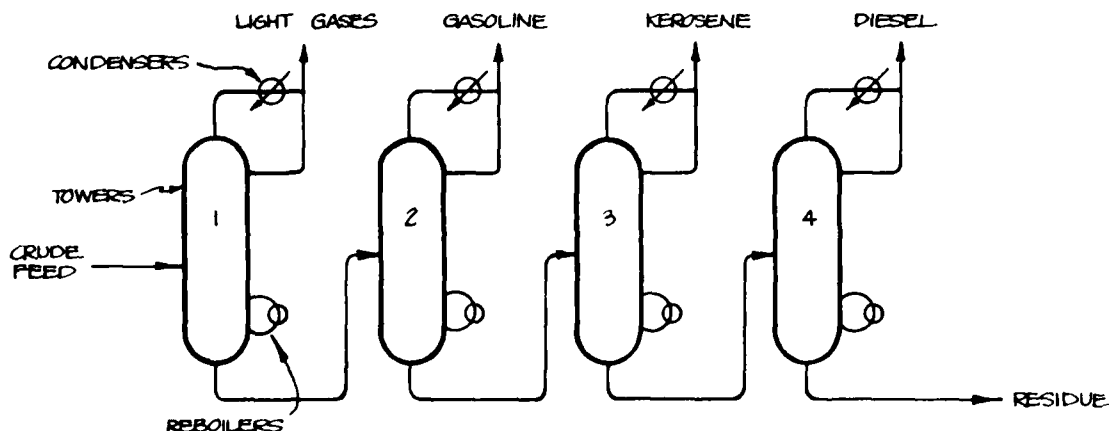


Fig. B-11. Separation by successive flash fractionation.

Sample Calculation. — The calculation results from fractional distillation of a Pennsylvania type crude, with steam injection, are shown in Fig. B-12. The capacity is 1,200 barrels/day. At the selected datum temperature\* 576°F the gasoline, naphtha, kerosene, and diesel are vapors, and the reduced crude oil is a liquid.

\* The datum temperature is the temperature about which the design of the tower hinges. By using this datum, the heat balance consists of the heat required (1) to vaporize the fractions, (2) to cool each product from the vaporizer temperature to its withdrawal temperature, (3) to condense the products that are withdrawn as liquids, and (4) reflux computation where necessary.



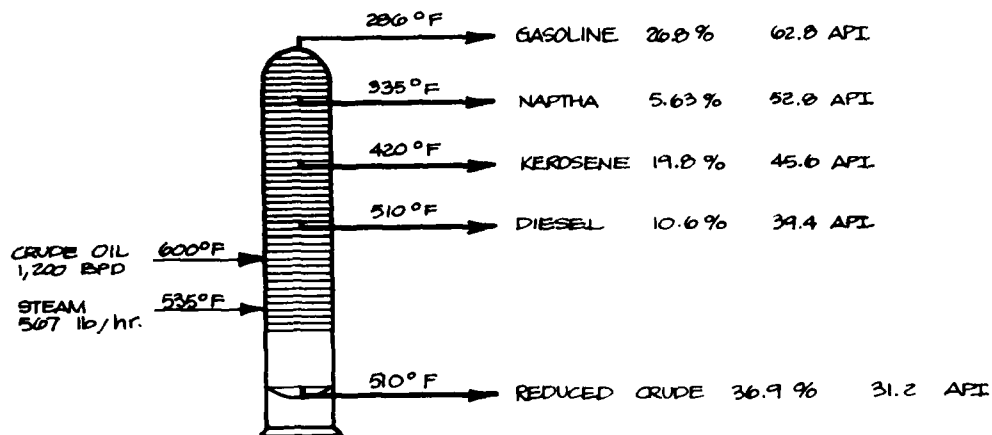


Fig. B-12. Simple tower system with materials balance.

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Unclassified  
163 pages

The report describes the initial testing of a self-help manual developed for application by U.S. industry to help reduce industrial vulnerability to a nuclear event; it is expected to have application to natural disasters as well.

In the first phase of the program, purely analytical procedures were applied at a number of industrial sites by personnel familiar with weapons effects and at a few of the same plants by in-plant personnel inexperienced in weapons effects. In the second phase, actual hardening exercises were carried out both by personnel familiar with the manual and also entirely by plant personnel, unassisted. These operations were documented with slides and/or movies, and information was obtained on time and personnel logistic requirements to complete the hardening efforts. The results of the analyses and the comparisons made suggest significant benefits from self-help industrial hardening might be expected.

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